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Journal of
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VOL. XII, No. 6 DECEMBER, 1929

INTENTION IN MOTOR LEARNING

BY SIDNEY SANDERSON[1]
University of Pennsylvania

In the experimental study which follows learning is to be regarded as a re-adaptation of the individual to his environment or, more specifically stated, to a series of problems requiring coördinated muscular movements, an adaptation which results in an increase in efficiency and a decrease in the time consumed in solving the problems. Although no entirely inclusive and satisfactory theory of learning has been evolved from the voluminous literature of the last thirty years, much light has been shed upon various aspects of the general problem. When regarded from a pedagogical point of view, the amount, rate and limits of improvement, together with their determining factors and conditions, are of extreme importance.

Thorndike[2] has reviewed in considerable detail the experimental researches down to 1913, and since that time J. W. Baird and others[3] have continued the review of the general literature of the subject. Outstanding among the factors governing improvement is the necessity for intense effort in the details of the performance and a real interest in improvement. Book,[4] for example, has demonstrated that, particularly in such an act of skill as typewriting, improvement depends upon great effort devoted to the details of the process. Kitson,[5] investigating the daily progress of compositors

[1] The writer wishes to acknowledge the assistance rendered to him during the formulation and course of this problem by Professor S. W. Fernberger and to express his appreciation to those students who coöperated in the actual experimental work.

[2] E. L. Thorndike, *Educational psychology*, N. Y., 1913, vol. ii, chaps. 7, 8.

[3] J. A. McGeoch, The acquisition of skill, *Psychol. Bull.*, 1927, 24, 437–466 (for 1917–1927). See also annual reviews in the same journal prior to 1917.

[4] W. F. Book, The psychology of skill, *Univ. of Montana Publ. in Psychol.*, 1908 1, 1–181.

[5] H. D. Kitson, A study of the output of workers under a particular wage incentive, *Univ. J. Bus.*, 1922, 1, 54–68.

who were working under the incentive of a bonus system, found that the majority of the men studied during five months had increased their output far beyond the bonus point. The newer employees, less set in their industrial habits, attained the greater increase. Book and Norvell, too, have shown clearly in four types of acquisition that knowledge of the score and interest in improvement are essential in increasing the score. "Too much cannot, therefore, be said of the practical value of the mental set induced by the special conditions arranged in our experiments as a facilitating agency in human learning. It makes the learner a different reacting agent, more ready to exert himself on the task in hand, more ready to make the right responses, and makes it easier for him to select the responses that are successful." [6]

Meumann, again, thinks that "one of the most important results of our recent investigation of the process of learning is the discovery of the extraordinary influence which the different intentions or attitudes (Einstellungen) of the learner exert upon his whole memorial process and upon his memorial result. It may be shown that there is a highly differentiated attitude of learning, and that memorial results are determined in a highly differentiated fashion by the attitudes or intentions of learners." [7]

Experiments with purely ideational materials, such as those of Ebert and Meumann, Aall, Mulhall and Peterson,[8] indicate that determination or intent to recall only certain aspects of the work or intent to recall at a later period is more efficacious than recall in which this attitude is not specifically induced.

In acts of skill and in ideational learning, then, the intention or mental set which may be the very general 'will to learn,' or a more specific attention to one phase of the learning, is found to determine to a great extent the course of the learning. At present there is no completely adequate psychological or neurological explanation of this fact.

The purpose of the present investigation was to study the effect on motor learning of a specific mental set or intent instilled in the learner without his awareness of its particular future application. Two similar motor problems were selected; one, a stylus maze without culs-de-sac; the other, a number-sheet, a sheet of paper with numbers printed on it in such an arrangement that a line drawn in order from 1 up to 40 would trace the same maze pattern. The intention

[6] W. F. Book & L. Norvell, The will to learn, *Ped. Sem.*, 1922, 29, 357.

[7] E. Meumann, *The psychology of learning* (J. W. Baird, tr.), New York, Appleton, 1913, 303.

[8] E. Ebert & E. Meumann, Ueber einige Grundfragen der Psychologie der Uebungsphänomene im Bereiche des Gedächtnisses, *Archiv. f. d. ges. Psychol.*, 1905, 4, 1–232; A. Aall, Die Bedeutung der Zeitperspektive bei der Einprägung für die Dauer der Gedächtnisbilde, *Ber. über d. V. Kongr. f. exper. Psychol.*, 1912, 237–241; Ein neues Gedächtnisgesetz, *Zsch. f. Psychol.*, 1913, 66, 1–50; E. F. Mulhall, Experimental studies in recall and recognition, *Amer. J. Psychol.*, 1915, 26, 217–228, and J. Peterson, The effect of attitude on immediate and delayed reproduction, *J. Educ. Psychol.*, 1916, 7, 523–532.

was created by specific instructions to learn the pattern of one of the problems as quickly as possible. The effect of these instructions was studied in the subsequent learning of the other similar problem. Two orders of experimentation were employed. Some subjects first learned the number-sheet then immediately learned the maze, after which they relearned the number sheet; others learned the maze then the number-sheet, which was followed by a relearning period for the maze.

The specific problems herein involved may thus be stated.

(1) To study the effect of an apparently unrelated intent in learning a number-sheet or a maze upon the subsequent learning of a maze or number-sheet by comparing the results of groups who learned under this intent with those who did not.

(2) To determine the effect of the intent on the learning of the first problem.

(3) To investigate the effect of the learning of one problem upon the learning of the second.

(4) To study the effect, with and without the special intention, upon the repetition of the first problem after the completion of the second.

(5) To investigate individual and sex differences in the learning involved.

METHOD

Apparatus. Fig. 1 shows the pattern of the maze utilized in this experiment; a single path, with no culs-de-sac, leading by a series of rectilinear turns from the starting point *A* to the finish *Z*. A $\frac{1}{4}$-in path was cut in a piece of $\frac{1}{16}$-in sheet brass, $9\frac{1}{2}$ in x 12 in. Small brass pegs, $\frac{3}{8}$-in long, soldered to the under side of the maze, raised it $\frac{3}{8}$-in from the wooden base to which it was fastened by machine screws through the base into the pegs. The outside dimensions of the completed maze were $10\frac{1}{2}$ in x 13 in. The stylus, a brass rod $1\frac{1}{8}$-in in length with a maximal diameter of $\frac{3}{16}$-in, was topped at one end with a wooden ball handle and the other end terminated in a $\frac{3}{8}$-in brass disc. Another brass disc, $1\frac{1}{8}$-in in diameter, at the base of the handle, prevented the fingers of the subject from touching the maze, and at the same time allowed the stylus to move freely in the grooves without touching the wooden base. Circular enlargements of $\frac{1}{2}$-in diameter at *A* and *Z* allowed the insertion or removal of the stylus at those points only. A wooden cover with spring catches covered the maze when not in actual use.

The printed number-sheet (Fig. 2) consisted of a sheet of paper coated on one side, $8\frac{1}{2}$ in x 11 in, on which all the numbers from 1 to 40 ($\frac{1}{4}$-in high) were arranged in such a manner that a continuous line drawn through the numbers in order from

1 up to 40 would reproduce the path of the maze. An arrow in the right-hand margin of the sheet showed at a glance the position of number 1, the starting point.

References to positions in the maze have been made in terms of the same position on the number sheet. For example, the starting pathway of the maze would be specified by 1–3.

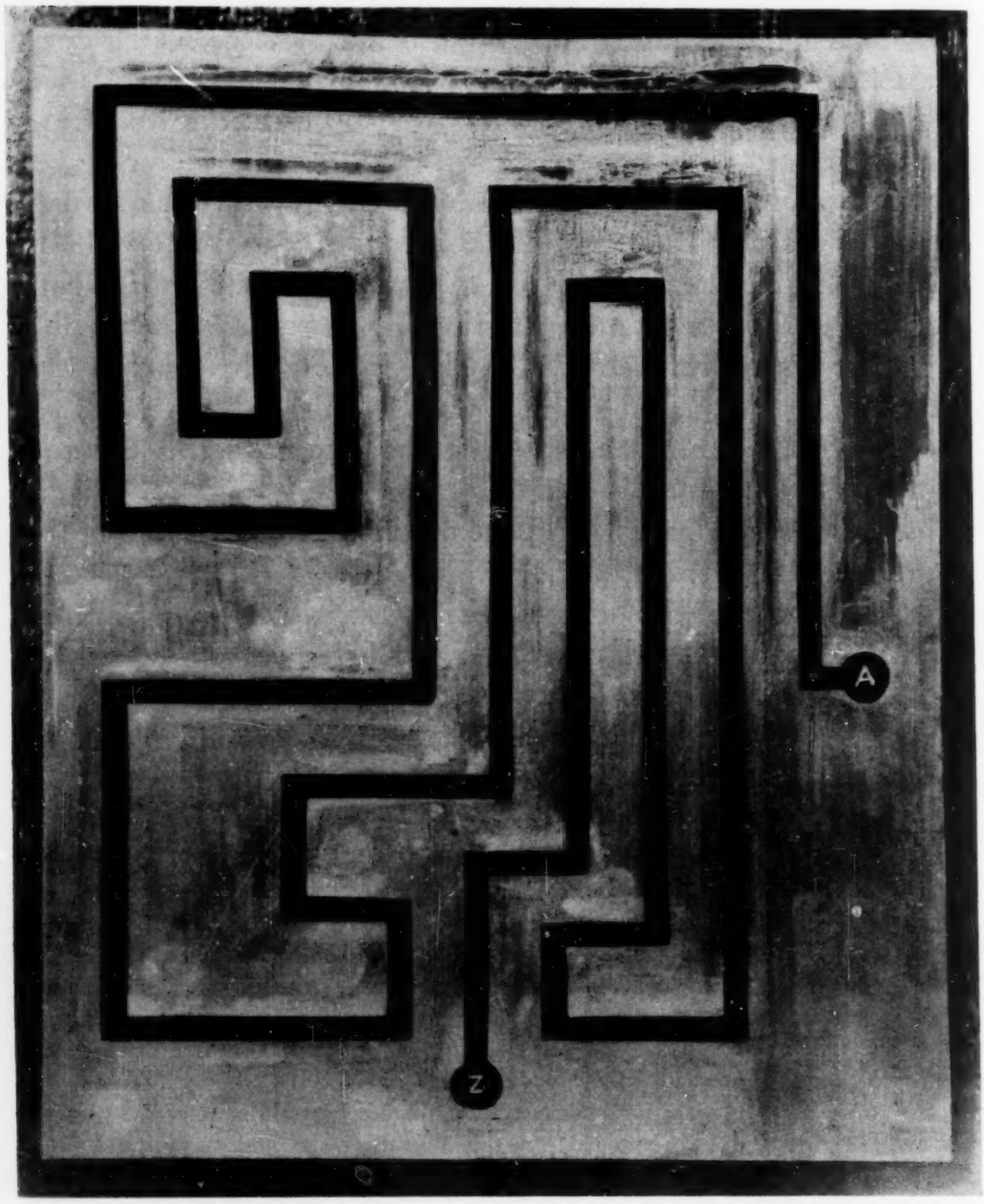

FIG. 1.

To maintain the similarity of problems the maze obviously had to contain no culs-de-sac, and yet, to present a problem of a reasonable amount of difficulty, the design had to be of a certain complexity. This was attained in several ways: (1)

several vertical paths of approximately equal length were grouped together in a parallel position on the right hand side of the maze, the proximity of these paths making it extremely difficult for exact orientation; (2) the positions of the maze corresponding to numbers 19, 20, 23, 30, 31, 32, 38 and 39 of the number-sheet were close enough to the true goal to confuse the subject; (3) the reverse turn, corresponding to the line through 9, 10, 11 and 12, presented a real obstacle.

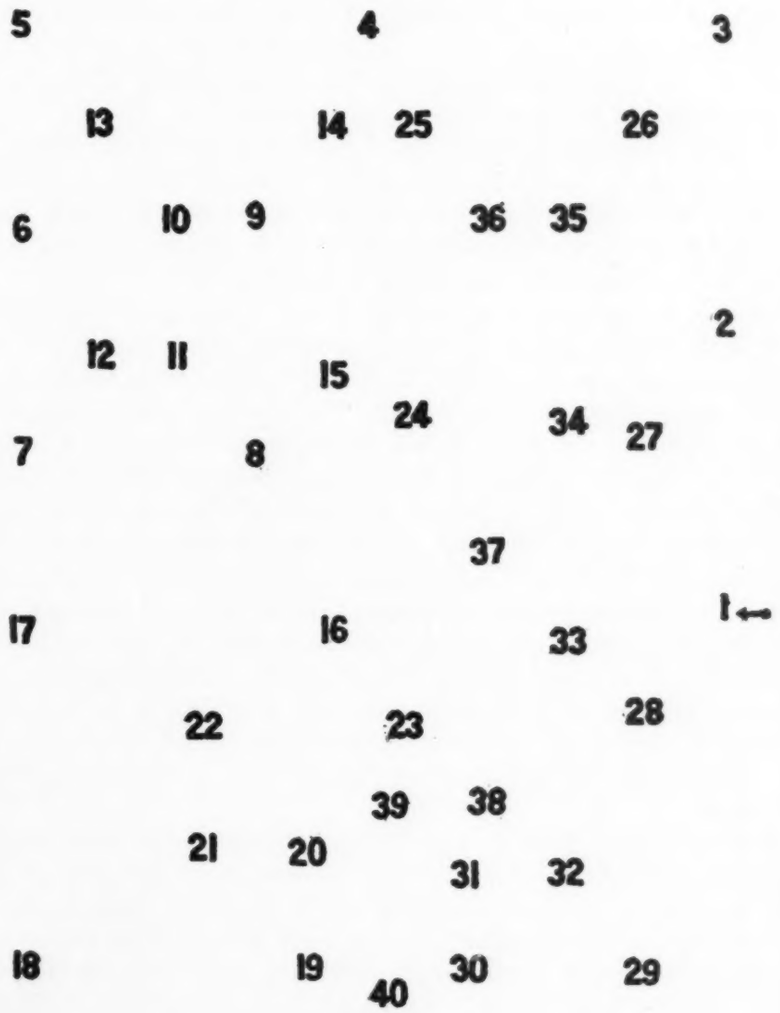

FIG. 2.

The subjects. The individuals who coöperated in this experiment were all from the University of Pennsylvania, most of them belonging to the three upper classes. The majority were drawn from the introductory classes in psychology; only in a preliminary experiment were a few graduate students employed. Participating in the work was a total of 128 males and 64 females, divided as follows; 7 males and 1 female in the preliminary experiment, and 121 males and 63 females in the main experiment, of whom 2 males and 2 females were dropped because of inability to complete the assigned problem in the time at their disposal.

With the exception of one or two, the Ss in the principal experiment were naïve to the maze situation. On the other hand, practically all of them had performed a

class experiment in 'speed of exploration' involving one trial of a number-sheet on which large numbers from 1 to 50 were arranged in haphazard order.

The subjects in the main experiment were divided into four groups. Group I consisted of 35 males and 15 females, Group II 35 males and 15 females, Group III 23 males and 17 females, Group IV 26 males and 14 females.

Conditions of the experiment. As the single working period for each S required from fifteen minutes to one hour, depending upon the individual ability, appointments were made at half-hourly intervals, from 9 to 5 o'clock during the day, at the convenience of the experimenter and the subject. With the exception of 5 cases, in which the work was done in the evening and in another building, all the experimental periods were completed during the day in a single room.

The Ss were assigned to groups in the order of their arrival, the first to Group I, the second to Group II, the third to Group III, the fourth to Group IV, the fifth to Group I, etc. This procedure was followed until there were 40 in each group, then, as neither Groups III nor IV had produced particularly significant results, the remaining 20 subjects were assigned alternately to Groups I and II.

The student in the 'general psychology' course is continually participating in a variety of group tests in which his individual rating in that group is secured. In order to eliminate any emotional disturbance which might hinder his work and also to secure full coöperation, the S was assured that he was not being 'tested' but that he was to do a problem which was within his ability and for which a large number of results were desirable because of the differences in solution. He was further assured that individual results would not be published. In a few cases there was a tendency to give up the job, but practically all coöperated to the best of their ability.

The subject, seated at a desk, was allowed to adjust his distance from it to suit his own comfort. A large blotter, on which were marked the outlines of two rectangles, one within the other, the size of the base of the maze and of the number-sheet, respectively, was placed on the desk directly in front of him. The number-sheets were at his left, face down, and, as used, were placed one at a time in position within the smaller rectangle. When the maze was employed, its position was within the large rectangle. In this way the spatial arrangement of the two pieces of apparatus was always the same.

For the number-sheet the subject used a pencil, and for the maze the special stylus. He was permitted to use either hand, but only three of the Ss preferred the left hand. During the trials of the maze S was securely blindfolded with a large black silk scarf, by which light was effectively excluded. One hand was placed on the stylus at the start, and the other allowed to rest on the side of the base of the maze to maintain its position. Between trials the experimenter lifted the subject's hand and the stylus from the finishing point and inserted the stylus in the hole at the start.

Groups I and II did 10 trials of the number-sheets, then 10 trials of the maze, followed by 10 more trials of the number-sheets. Groups III and IV did 10 trials of the maze, 10 trials of the number-sheets, and then 10 trials of the maze. The subject had no information concerning the experiment or the number of trials which would be required during the progress of the work.

The order of experimentation was the same for Groups I and II, and also for Groups III and IV; but since the instructions differed, Groups I and III may be regarded as control or standard groups and Groups II and IV as stimulus groups.

All instructions were read to the subject before the start of any series of trials. If they were not perfectly clear, they were re-read. In one or two cases the term 'maze' required more specific explanation.

The 30 trials were completed in one session, with a brief rest period following each series of 10 trials. Additional rest was allowed between maze trials if S required it; but no set schedule of rest periods was adopted because some needed more rest than others.

The subjects were cautioned at the end of the session to give no information at all to other students concerning the experiment. The writer feels reasonably sure that all Ss were ignorant of the apparatus and method involved in the procedure.

The instructions for Group I were as follows:

(*a*) "I have given you, face down at your left, several sheets of paper. On each sheet there are scattered in haphazard order numbers from 1 to 40. I will give three commands: 'ready,' 'turn,' 'go'; at 'ready,' prepare to turn; at 'turn,' turn over the top sheet from right to left and place your pencil on number 1 which you will find about half way down the right hand edge of the sheet; at 'go,' draw a straight line from 1 to 2, from 2 to 3, from 3 to 4, and so on, in regular order, up to 40. *Connect the numbers as quickly as possible, but be sure you draw the line in regular order through each of the numbers. When you reach 40, put the sheet aside, face down, and await the signal for the next trial. Work as rapidly as possible, but be sure the numbers are connected in order. 'Ready,' 'turn,' 'go.'*"

After the completion of the required number of 10 trials the subject was blindfolded, the maze put in position, and the following instructions read:

(*b*) "For the next part of the experiment you are to work, while blindfolded, on a maze which consists of a number of pathways in which a metal stylus or pointer can be moved from a starting point to a goal or finishing point. At the command 'ready,' your hand will be placed on the stylus at the starting point; at 'go,' you will move the stylus as quickly as possible through the various pathways until you reach the hole at the finish where the stylus can be lifted from the board. Do not touch the face of the maze with your fingers. When you have finished, await the signal to commence the next trial. . . . 'Ready,' 'go.'"

The experimenter demonstrated how the stylus could be lifted from the board at the start and explained that there was a similar hole at the finish, but that in between the stylus could not be removed from the groove. If S reached the goal and turned back without realizing it, he was stopped and informed that it was the finish. If, as many did, he returned to the start and removed the stylus, it was immediately replaced and he was told that he had lifted it from the starting point. After 10 trials of the maze, the blindfold was removed and the following directions were given:

(*c*) "Now I am going to give you some more trials with the number-sheets. . . . 'Ready,' 'turn,' 'go.'"

Group II worked under the same instructions as Group I, except that for the italicized section of part (a) there was substituted the following:

"*You are to learn the pattern formed by these lines in such a way that I may call on you to reproduce it at the end of the learning. When you reach 40, put the sheet aside,*

face down, and await the signal for the next trial. Connect the numbers in order as rapidly as possible, but the primary problem is to learn the pattern. . . . 'Ready,' 'turn,' 'go.'"

Instructions (*b*) and (*c*) were identical for Groups I and II.

For Group III the order of directions was reversed. The Ss worked first with the maze, using, with the omission of the first phrase ('for the next part of the experiment'), the same instructions as Group I. Then followed 10 trials with the number-sheets, again employing the (*a*) instructions of Group I with the additional introductory phrase ('for the next part of the experiment'). After this a final series of 10 trials with the maze was given under these instructions:

"Now I am going to give you some more trials with the maze. . . . 'Ready,' 'go.'"

Group IV, on the other hand, learned the maze under the following instructions (the italicized portion represents changes):

"*You are to learn, while blindfolded, the pattern of a maze in such a way that I may call on you to reproduce it at the end of the learning.* The maze consists of a number of pathways in which a metal stylus or pointer can be moved from a starting point to a goal or finishing point. At the command 'ready,' your hand will be placed on the stylus at the starting point; at 'go,' you will move the stylus as quickly as possible through the various pathways until you reach the hole at the finish where the stylus can be lifted from the board. Do not touch the face of the maze with your fingers. *Work as rapidly as possible, but the primary problem is to learn the pattern of the maze.* When you have finished, await the signal to commence the next trial. . . . 'Ready,' 'go.'"

Following 10 trials of the maze under *pattern* instructions, 10 trials of the number-sheets and 10 more of the maze were carried out under the directions used by Group II.

Hereafter, for convenience in identifying the various groups, Groups I and III, the control groups who worked for speed, will be referred to as *speed* groups and Groups II and IV as the *pattern* groups.

The time (to the nearest sec on a $\frac{1}{5}$-sec stop watch) of each trial of the number-sheet or maze was recorded. In addition, notes on the subject's objective behavior during the practice periods were made. Due to the construction of the maze, the only possible error was that of retracing. One trial of the maze was measured by the time required to traverse the path from start to finish without regard to errors; the measure of a trial of the number-sheet was again the number of seconds required to draw a straight line from 1 through each of the succeeding numbers to 40.

A preliminary experiment with 4 undergraduates and 4 graduate students working under the instructions of Groups I and III was conducted to determine the number of trials necessary to attain approximately maximal speed of solution. Two Ss, doing the numbers first, reduced their first trial records of 25 sec and 36 sec to 6 sec and 9 sec, respectively, at the end of the thirty-fifth trial.

During the first 10 trials, however, they attained times of 15 sec and 12 sec, respectively. On the other hand, those learning the number-sheet after the maze reduced their times materially in the first 10 trials, succeeding during the next 5 trials in only slightly improving their best times. Learning the maze, this same group displayed considerable variation in the first trial, the scores of which ranged from 64 sec to 380 sec; but in the eighth, ninth, and tenth trials these 6 persons markedly reduced their time. The best times in these 3 trials ranged from 9 sec to 19 sec, a range which an additional 5 trials lowered to only 8 sec to 18 sec. It was then decided that 10 trials offered a sufficiently long practice period to master either the maze or the number-sheet.

Results

1. *Objective behavior of the subjects in the maze and with the number-sheet.* It is clear that a continual forward movement in the maze would lead to a rapid completion of it. The pattern, however, was of such a nature that subjects were not certain, even after the completion of many trials, that no culs-de-sac were included in its design. Surprising though it may seem, one S reported that he thought he was solving a different pattern during each of his 20 trials.

There was a marked difference in the attack on the maze; some individuals moved at great speed, blindly following the path that offered the least resistance, be it forward or backward; others moved with extreme caution, speeding up when this method seemed to be leading to no result; still others attempted to force their way through the brass plate at the turn, or pull by force the stylus from the groove. At one time or another, 'trial-and-error' movements were characteristic of every subject.

In the early trials many of the subjects, reluctant thoroughly to explore the longer paths, returned quickly to a region of many turns and short paths. This tendency was most obvious after one solution of the maze, during which the subject learned the general location of the goal, for then paths 23–25 or 32–35 appeared to lead directly away from the finish.

The retracing errors were so frequent that many of the participants were at a loss to gauge the approximate distance travelled in a correct solution. Often exploration of the left side only of the maze would be continued for a long period. Time after time, the reverse turn in the upper left-hand corner was traversed in both directions, with no progress beyond that point for a considerable time. Others passed that obstacle with no difficulty, only to stick at turns 19–21 or 29–31. A forceful movement with a loosely held stylus would often carry the subject by chance around a turn, opening up new possibilities of adventure.

Despite the fact that the first four straight paths, which practically every subject travelled without error, revealed all the turns possible at any point, few individuals attempted all the possibilities when the end of any one path was reached. Random rather than systematic movements seemed to be preferred. The assumption that it was a blind alley caused the individual to retrace his steps.

The turn 8–13 required a movement like the letter S. A rapid wrist movement carried many through it; but others, failing to reach the end of path 11–12 at the completion of the movement, returned to 8, apparently always moving in a forward direction. This disoriented a great many of the Ss.

One man, after completing 16 trials of the maze, worked for over 6 min on the seventeenth trial, only to arrive time after time at 31. At first his reaction to this assumed blind alley was to retrace his steps to the beginning, but later angered at his inability to arrive at any other point he reacted to this situation by trying to force his way in a vertical direction. It was only after a suggestion that he might more easily take a path already cut out than make a new one that he moved to 32 and completed the trial. His results for the last 4 trials were not recorded.

Consistently high time scores and numerous errors indicate that in 10 trials the maze had not been sufficiently learned. This was apparent in relatively few cases; six in Group I, one in Group II, four in Group III, and four in Group IV.

Some subjects made consistent improvement, apparently profiting from former trials; others were greatly confused even after several successful trials. Generally, the last two or three trials brought out the best reactions.

Four Ss, all of whom had been extremely variable in the first series of the maze, had some difficulty during the second series; but practically all the other Ss completed the last 10 trials in rapid time.

The error in the number-sheet trials which tended to lengthen the time record was a failure to connect the numbers in order; *e.g.*, to go from 23 to 34, from 39 to 30 or from 38 to 40, necessitating a new start at the point of error. Most of the Ss in the early trials drew the line from number to number, stopping each time to seek the next number. Speed was attained only with a continuous movement of the pencil. Sharp drops in time occurred when this procedure was adopted. Some, however, failed to learn this method.

One subject in each group was forced to abandon the experiment; a female in Group I, after working half-an-hour to complete 4 trials of the maze, had to leave to attend a class; a man in Group II completed 7 trials of the maze in 45 min and then stopped; a girl in Group III became so emotionally upset after 20 min in the maze, doing 4 trials, that she asked to stop, and finally, another male had to cease work because he had completed only 1 trial of the maze in over 20 min and showed no signs of learning it.

2. *The effect of a specific intention induced in one problem upon the subsequent learning of a second problem.* As each individual in a group completed (without regard to possible errors) 30 trials, divided according to the particular group between the two problems, the criterion employed was the time in seconds to complete each of the trials. By the nature of the design, errors were almost impossible with the number-sheet, and quite frequent in the maze. And as both orders were utilized, the most constant measure appeared to be the time employed. Table I shows the average time results for each of the 30 trials completed by Groups I and II. In addition to the average, there are included the lowest, the highest and the approximate median scores for each trial in order to furnish some general idea of the variability of the groups. The minimum and the maximum indicate the range, and the median represents the twenty-fifth score from the low end of the distribution. Other measures of variability were not calculated due to the small size of the groups

involved. The average deviation, *e.g.*, in many trials of the maze was larger than the average. On the whole, then, these three measures are indicative of the variation which occurred, particularly in the maze series.

TABLE I

AVERAGE RESULTS FOR SPEED GROUP (I) AND PATTERN GROUP (II)

Trials	Group I (speed group)				Group II (pattern group)			
	Numbers							
	Ave.	Min.	Max.	Med.	Ave.	Min.	Max.	Med.
1	37.2″	21″	77″	35″	41.3″	21″	75″	40″
2	28.5	17	71	26	29.9	20	54	27
3	24.4	16	37	23	26.6	15	58	26
4	22.6	15	38	21	24.4	16	45	23
5	20.9	14	49	20	23.8	15	44	22
6	19.2	13	32	20	22.4	13	52	21
7	18.7	12	48	18	20.9	11	35	20
8	17.8	10	32	17	19.5	9	33	19
9	17.2	10	26	17	19.2	10	32	20
10	16.6	9	27	16	18.4	9	27	18
	Maze							
1	80.6	17	354	50	61.0	21	396	35
2	75.7	10	769	45	66.4	11	703	26
3	80.4	11	547	28	42.7	11	219	21
4	44.1	9	237	23	29.2	10	140	21
5	53.8	10	465	21	28.0	9	187	21
6	46.3	9	257	23	29.2	9	449	18
7	36.2	7	186	23	24.7	9	132	17
8	34.1	9	289	20	22.6	7	172	17
9	31.6	8	122	19	19.1	7	59	16
10	23.3	7	98	16	21.1	7	89	15
	Numbers (2nd series)							
1	15.6	10	25	15	16.4	11	25	15
2	14.8	10	23	14	15.9	10	30	15
3	14.4	9	20	14	15.3	9	22	15
4	13.9	9	20	14	14.8	9	25	14
5	13.6	9	23	13	14.5	8	22	15
6	13.4	7	30	13	14.0	7	23	14
7	13.1	9	20	13	13.9	8	26	13
8	13.0	7	19	13	13.7	7	23	14
9	12.6	8	18	12	13.6	7	25	14
10	12.0	7	17	12	13.1	7	20	13

Examining the results of Groups I and II, it is noted that Group I, the control or *speed* group with the intention to work for speed, showed a consistent decrease in time from the first to the tenth trials, a rapid drop from the first to the second, and then a slower, continuous drop. On the other hand, Group II, the stimulus or *pattern* group under the mental set to learn the pattern as quickly as possible,

showed a corresponding set of results, except that the scores were consistently higher for all trials.

Both these groups, having had the same amount of visual and kinæsthetic guidance from the numbers, then transferred to the stylus maze which they learned under the same directions, *i.e.* for speed only. The *pattern* group, however, averaged on the first trial 24 percent better than the *speed* group, 61 sec compared with 80.6 sec for Group I, an advantage in time which was maintained throughout all the trials, although the tenth trial was only 10 percent better.

The intention to learn the pattern of the number-sheet evidently had a beneficial effect when that group attacked the maze problem, one requiring similar movements to complete.

The group which learned the number-sheet with directions for *speed only* was using a natural method, adapting the output of energy to suit the individual need in the solution of the problem. Undoubtedly vague visual concepts were constructed consciously, but the subject's intention was directed particularly to a rapid completion. As vision was not obstructed and there was no indication of the maze to follow, it was apparently unnecessary to memorize the pattern itself. The *pattern* group, on the contrary, used a method which was unnatural in learning a problem of the type exemplified by the number-sheet. Irrelevant elements —phases of the pattern—required active discrimination and memory, a distribution of attention which would be detrimental for a rapid completion. Accordingly, one might expect the increased score returned by this group.

This active process of memorization, however, proved to be highly useful when both groups were instructed to work for speed on the stylus maze. The *pattern* group profited by experience to the extent that they were able to eliminate many of the movements displayed by Group I, the *speed* group. The original attitude of pattern-learning had served to fix more firmly the proper reactions required to solve the maze.

Table II shows the progressive effect throughout the maze

series for both the pattern and the speed groups. The time of the last trial of the number-sheet is employed as the criterion for the final learning of that problem. And the increase from that score of the averages of the first 3 trials, the first 5, the last 3 and the last 5 of the maze series is indicated as an actual increase in seconds and as a percentage. A low difference score or low percentage marks the approaching equality of the maze times to the time of the last trial of the number-sheet.

TABLE II

DIFFERENCE BETWEEN LAST TRIAL WITH NUMBER-SHEET AND AVERAGE OF FIRST 3 TRIALS, ETC. WITH MAZE FOR GROUPS I AND II

Group combined M and F	First 3 Actual gain	First 3 Gain percent	Last 3 Actual gain	Last 3 Gain percent	First 5 Actual gain	First 5 Gain percent	Last 5 Actual gain	Last 5 Gain percent
I	62.3″	375	13.1″	79	50.3″	303	17.7″	107
II	38.3	208	2.5	14	27.1	148	4.9	27
Males								
I	64.4	390	12.8	78	52.2	320	16.4	99
II	34.1	181	0.3	2	22.6	120	1.5	8
Females								
I	57.5	342	13.7	82	45.8	273	20.8	124
II	47.9	272	7.7	44	37.4	212	12.8	73

Assuming that Group II worked as rapidly as possible on the number-sheet, it is found that the actual effect of the directions under which they worked when carried over to the maze was effective throughout; but that the extension of practice was quickly bringing the groups to the same level, for the time and percentage gains were less in the last 3 trials. The intent to learn the pattern of the numbers, without the subject's knowledge, brought about a different reaction to the maze situation, a rapid elimination or complete avoidance of many of the useless moves made by Group I, the *speed* group.

In order to show the validity of the average results for Groups I and II (as indicated in Tables I and II), curves were made for each group to present graphically the actual distribution of the averages for the first 3 trials of the maze, the last 3, the first 5, and the last 5 of the 50 individuals in each group. Another set of four curves grouped the cases in step-intervals of 10 sec. In this manner the effect of the

extremely high scores is more noticeable. All of these curves display a larger grouping of cases from the *pattern* group than from the *speed* group around the low end of the scale. As might be expected, this advantage is most apparent for the first 3 trials, diminishing slowly for the first 5 and last 5, and being insignificantly small for the last 3 trials.

Curves were similarly constructed to show the distribution for each of the cases in the two groups of the difference between the last trial of the number-sheet and the averages of the first 3 trials of the maze, the last 3, the first 5 and the last 5. As variation appears to be characteristic of maze learning, there is no justification for the elimination of the extreme cases. Both sets of curves, those in which the cases were grouped in intervals of 10 sec and those in which they were not, indicated again a preponderance of Group II cases toward the low end of the scale. Again, the superiority of this *pattern* group was most marked in the early trials, the first 3 and 5, but the advantage persisted even during the last 3 trials.

For Groups III and IV, of which the first can be regarded as the *speed* group and the latter as the *pattern* group, the order of the problems was reversed, the maze learning preceded the numbers. Consistent improvement was not made by either group, the pattern group starting higher, but ending slightly below the speed group in the tenth trial. At this point the speed group increased considerably, 9.3 sec above the time of their ninth trial. Table III shows for Groups II and IV the averages, the minimum, the maximum and the median score for each of the 30 trials completed by these groups. An examination of the results for the first series of the maze discloses that in a majority of the trials the *pattern* group scores higher than the *speed* group, a result similar to that attained by Groups I and II.

In completing the series of trials with the number-sheets, both groups finish with average scores that are relatively little different. The difference in directions under which these groups learned the maze evidently had no effect on a problem in which visual guidance was dominant over any

kinaesthetic pattern which might have been formed in the maze. Such practice, however, was not detrimental but rather beneficial to both groups for they did the first 5 trials of the numbers in less time than Group I, the members of which had no previous practice in the movements required.

Table III

Average results for speed group (III) and pattern group (IV)

Trials	Group III (speed group)				Group IV (pattern group)			
	Ave.	Min.	Max.	Med.	Ave.	Min.	Max.	Med.
				Maze				
1	79.7″	16″	339″	58″	109.8″	30″	589″	77″
2	101.3	13	708	30	65.0	16	374	36
3	67.6	14	365	32	78.7	15	495	33
4	51.2	9	403	24	65.5	17	423	31
5	49.1	10	450	30	56.3	15	387	28
6	41.3	10	182	29	45.7	13	261	24
7	31.8	8	210	18	34.8	13	158	24
8	24.6	8	115	18	44.2	12	354	21
9	26.5	6	140	17	42.0	11	390	21
10	35.8	6	275	16	30.6	11	164	21
				Numbers				
1	33.9	20	107	30	32.5	20	53	32
2	26.5	18	61	24	26.7	18	44	26
3	23.3	16	54	21	23.2	16	32	23
4	21.1	15	38	19	21.6	14	30	22
5	19.6	13	32	19	20.0	13	31	20
6	19.0	13	32	18	18.6	12	25	19
7	17.7	12	25	17	17.9	12	25	17
8	16.9	11	23	16	17.8	12	23	18
9	16.7	11	25	17	16.5	11	23	16
10	15.8	11	22	15	16.0	10	23	15
				Maze (2nd series)				
1	19.4	8	87	16	23.4	9	93	19
2	18.2	8	53	15	21.3	8	52	18
3	16.5	8	63	14	19.6	8	50	17
4	16.3	7	45	13	21.3	7	184	16
5	18.5	7	88	13	20.2	7	141	15
6	14.4	7	41	13	16.8	7	44	14
7	16.1	6	66	12	23.4	6	167	15
8	13.3	6	28	12	23.2	6	164	14
9	12.5	6	52	12	17.0	7	105	14
10	12.1	5	29	12	15.4	7	42	14

If the tenth trial of the maze is taken as a criterion of learning and the difference between this trial and the first 3 trials of the number-sheet, the last 3, the first 5 and the last 5 calculated in actual time and in percentage of gain, as was done for Groups I and II in Table II, it is discovered that Group III, the *speed* group, made the greater gains through-

out. On the other hand, as the maze results were variable and a consistent improvement did not occur, a better criterion for maze learning might be the average of the last 3 trials. If this average is used to calculate the actual gain or percentage of gain, the result is reversed, for Group IV, the *pattern* group, then shows the greater gain. From the objective behavior of the subjects in these groups, it is more reasonable to conclude that both groups carried over a general pattern of arm movement, that vision predominated as the guide and that practice on the maze was equally beneficial, that is, whatever recognition of pattern did occur was equally divided.

One can conclude that a kinaesthetic pattern becomes much less effective than visual guidance when transferred to that kind of a problem which involves vision to a considerable extent.

3. *Learning a problem under different directions.* An examination of Tables I and III discloses the fact of a difference between the pattern groups (II and IV) and the speed groups (I and III) in learning the two problems as measured by a series of 10 trials. Group I worked on the numbers with directions for speed, while Group II was instructed not only to work as fast as possible, but to learn the pattern as sketched. This diversification of intention had a slightly detrimental effect on the speed as shown by the higher times for Group II, an increase directly traceable to the sort of instructions given. Working on the maze Group III, the *speed* group, in general turned in lower times than the *pattern* group; but again it might be expected that specific instructions to learn the pattern would be effective in increasing the time. To master such a difficult problem as the maze-pattern, or even that of the number-sheet, speed would necessarily be sacrificed to some extent. The number of trials was insufficient really to learn to reproduce the pattern; and both the pattern groups, to comply with the instructions, were unable to work at the maximal speed and still grasp this pattern.

The effect of different intentions is very apparent even

in such relatively simple movements as those involved in these two problems. Directions must be worded in such a way that they will lead to the particular mental set which is being sought in any experimental or testing situation. Distributed 'attention' resulting from the *pattern* intention is less effective in the original learning of the numbers or stylus maze than such diversification of the 'attention' as the subject naturally uses in solving the problem as fast as possible.

4. *Practice effects of one problem upon the other.* Although the two problems, the maze and the number-sheet, were similar in design, the actual learning activities involved were quite different under the conditions of the experiment. The length of the paths and the various turns of the number-sheet were learned chiefly by visual perception which was aided in the later trials by kinaesthetic guidance; but in the maze tactual and kinaesthetic experiences were depended upon primarily, any verbal or visual concepts of pattern being an outgrowth of these. A comparison of the results of Groups I and III for the maze and the number-sheets indicates that any practice effect was most noticeable in working on the numbers after the maze. Group III scored an average of 33.9 sec in the first trial of the numbers and 15.8 sec in the tenth, while Group I, working on the numbers with no maze practice, scored 37.2 sec and 16.6 sec for these trials. The initial benefit of the maze trials was rapidly lost as the series continued, Group III maintaining only a negligible lead in the last trial. The mechanical guidance through the maze probably built up some sort of a vague kinaesthetic pattern which was carried over to the number-sheet. This was more readily adapted to a visual problem than the reverse situation.

Illusions of extent of movement play a part in the stylus maze situation. Similar movements with and without visual guidance seem of unequal length. When passing from the number-sheet to the maze this disparity was plainly noticeable, the subjects being unable to recognize the long pathways, particularly as different from one another. Group I were less likely to recognize their second problem, the maze, as similar in pattern to that of the numbers than Group III, who were able to check more easily their kinæsthetic perceptions built up in the maze when they next worked on the number-sheet, their second problem.

The situation in which the maze was solved before and after the number-sheet series (see Tables I and III) showed no clear-cut results. Group I, in working on the maze even after a practice series of the number-sheets, was able to score lower than Group III, doing the maze with no preliminary work, only in 3 of the 10 trials (second, fourth and tenth). This apparently indicated that the practice series had little or no effect, that the maze was solved as more or less of a new problem without a recognition of the pattern involved. The visual element may dominate the motor factors and is of little assistance in a new problem requiring fundamentally kinaesthetic perceptions. On the other hand, in the situation in which Group III worked, those kinaesthetic perceptions that the maze-learning developed were of distinct advantage in attacking the number-sheet.

An examination of Tables I and III for the second series of the numbers and the maze reveals the fact that a return to the original problem is followed by still different results. Group I starts the numbers slightly below the time of the tenth trial of the first series, producing a curve of continuous acceleration from the first to the tenth trials. These results, combined with those of the first series, show a uniform drop, with a rapid initial improvement, from the first to the twentieth trials. It is to be expected that 20 successive trials would give similar results. In other words, the introduction of 10 trials of the maze between the first and second series of 10 trials of the number-sheet had no beneficial or detrimental effect on the numbers other than to keep the subject 'in form.' The subject knew the number-sheet pattern so well at the end of the first series that no more clues useful in the reduction of time are secured from practice on the maze. Group II, the *pattern* group, reacted approximately the same way to a second series of the numbers. It is interesting to note that the rapid initial drop is not apparent in this second series of trials.

Group III, on the other hand, repeating the maze series, presumably benefits from the practice on the number-sheet. The time drops to 19.4 sec for the first trial, compared with 35.8 sec for the tenth trial of the first series.

Group IV also shows a considerable decrease in time. This suggests that the visual clue from the number-sheet practice periods following a number of preliminary trials with the maze furnishes valuable aid when the maze is repeated. The vague visual concept of pattern evolving from the cutaneous and kinaesthetic cues which many subjects have reported in other studies in maze learning, if present in this case, is revised and checked by vision.

5. *The continued effect of intention on relearning.* All groups, both *speed* and *pattern*, were required to repeat the first problem after the completion of the second problem. In examining the results of Groups I and II there is some evidence of a continued effect of the additional intent to learn the pattern, for Group II shows time scores always slightly above those of Group I (*speed*) during the second series of the numbers. This is checked by the comparison of the time records of Groups III and IV for the second series of the maze, for here, too, the pattern group scores higher than the speed group.

Despite the fact that all four groups carried out this second series under instructions that were similar in the sense that no emphasis was put on either speed nor pattern, it is probable that the original intention to learn the pattern retarded Groups II and IV. Group IV was lower than Group III in the tenth trial of the first series of the maze, but during the second series started higher and continued thus throughout the 10 trials.

Constancy of attitude and the assumption of the required attitude are difficult to maintain and retain without an introspective check and the continued repetition of proper instructions.

6. *Individual and group variations.* The columns headed minimum, maximum and median of Tables I and III present a general view of the individual variations within a group which, of course, the individual scores show more clearly. Extreme variation is more apparent in the maze results, and is, undoubtedly, a function of the kind of problem. The lowest score recorded in the maze is 5 sec while the

highest in any of the trials is 769. For the first trial of the groups (III and IV) working on the maze as the first problem, however, the lowest time is 16 sec and the highest 589. There is considerable variation in the individual scores for the whole maze series. Some individuals started out with a rather high score on the first trial, then decreased rapidly on the next trial, showing from then on a fairly consistent decrease through the succeeding trials of both the first and second series. Others started low, increased the time on the next trial, then varied considerably for a few trials.

Several subjects, most of them in Group I (maze after numbers) produced high and variable results, thus indicating no real mastery of the situation. In Groups III and IV this occasionally persisted in the first few trials of the second series of the maze. From time to time, a subject turned in a poor time trial in the middle of a series of good ones. Some were low from the beginning and improved continuously; others were high for the first 7 trials, improving only on the last 3. One subject scored her lowest time in the first series of the maze, and did not improve that time in the second series. A high first trial was followed at times by an extremely low second, only to give way to a series of high trials. Some displayed real improvement on the maze only during the second series. Initial low times scores were difficult to decrease materially as the slightest hesitation in movement, or a false move, tended to increase the score.

With the numbers, however, the range of individual variation was less marked. Some subjects were slow on the first trial, having had difficulty in finding certain numbers. In many of the trials the speed ranged from 7 sec to 107 sec; but even in the first trial the range was only 21–77.

The intention to learn the pattern had an effect in increasing the range among the subjects of Group II for the number-sheet, and of Group IV for the maze. Distribution curves for individual scores grouped in the averages of the first 3 trials, last 3, first 5, and last 5 indicate that Groups I and II vary differently on the maze, the former (*speed*) tending to a wider variation than the latter (*pattern*). This

difference in the range of scores decreases as the number of trials increases.

7. *Sex differences.* An analysis of sex differences was made by drawing up separate tables for men and women, similar to Tables I and III, and by constructing curves to show the distribution for the men of the averages of the first 3 trials, the last 3, the first 5 and the last 5 of the second problem—for Groups I and II with the maze and for Groups III and IV with the number-sheet. In addition, there were drawn curves of the distribution of the differences between the last trial of the first problem and the averages of the first 3, the last 3, the first 5, and the last 5 trials of the second problem. Table II depicts the actual gain and percentage gain for men and women separately. From Tables I and III, and their counterparts for men and women, were constructed group-learning curves for the men, for the women, and for the men and women together.

In Groups I and II there were 35 men and 15 women; in Group III, 23 men and 17 women; and in Group IV, 26 men and 14 women.

The results for the men and for the women of Group I compare very closely except that the men improve slightly more on the last trials. In Group II the women are a little superior to the men with the number-sheets; but in the maze they show a higher and more variable record. As Table II indicates, the effect of an intent to learn the pattern of the number-sheet is more striking for the men than for the women when applied to the subsequent learning of the maze. And the carry-over of this intent to a second series of the number-sheet results in no difference between Groups I and II for the women, but for the men of Group II the results are higher than those of Group I. Both men and women in Group IV, when compared with those of Group III, show higher scores in the second series of the maze.

All the maze results of the women are more variable than those of the men; but, of course, there are fewer cases from which to draw conclusions. The effect of the *pattern* intent is less marked on the women than on the men.

Discussion of Results

Although the pattern of the two problems used in this study was such that the same movements of the hand and arm were required in their solution, the working conditions —with and without visual guidance—brought about an apparent dissimilarity. With vision the maze can be completed more rapidly than the number-sheet because of the mechanical guidance of the grooves. Deprived, however, of the aid of visual perception the maze offered to the subject a real problem, not merely an act of muscular coördination.

Because of the extensive variations in the scores of the maze, it is essential that studies made in this type of learning should cover the results of a very large number of subjects. It is recognized that the groups included in this investigation are relatively small, and that the conclusions must be offered with a due amount of caution. The number of women, especially, is small; but as the general results for them disclosed about the same characteristic trends as did those of the men it was felt that their scores could be included in the total group. If anything, their results made the general changes less outstanding.

Unless the effect of specific conditions is markedly displayed in the data gathered from different groups working under different conditions, there is always the chance that any effect is merely the result of comparing groups of unequal ability. Heron,[9] for example, in discussing chance and individual ability states that he could not find groups of definitely equal ability. In intercorrelating results from five stylus mazes, he concluded that maze records are influenced by both chance and individual ability, that these two factors varied with the maze, that chance was sometimes more influential than individual ability, but that at no time was individual ability much more effective than chance.

There is no doubt from the objective behavior displayed in the maze of this study that chance played a part in learning some portions of it. But at the same time, the *pattern*

[9] W. T. Heron, Individual differences in ability vs. chance in learning the stylus maze, *Comp. Psychol. Monog.*, 1924, 2 (no. 8), 1–60.

group (II) produced results so decidedly different from those of the *speed* group (I) that it does not appear valid to assume such a great variation in individual ability.

As Book and Norvell[10] suggest, it is a question of great importance just how or why a group of special incentives, setting up a particular mental attitude, results in increases in score. This means that qualitative investigations of different kinds of learning are most essential in furnishing information along that line. The objective method used in this investigation should be checked by introspective reports; but it is exceedingly difficult to find a sufficiently large group of subjects who can at the same time render valid reports.

This experiment was undertaken to discover what effect a particular intention on the part of the subject would have on different kinds of learning, one a distinctly visual problem and the other primarily motor; its subsequent effect when carried over without the definite knowledge of the subject to a second problem; and finally its effect on the repetition of the first problem. As it was felt that a pattern of response was primarily important in improvement in acts of skill, the particular aspect of the 'will to learn' or intent selected was the emphasis on the pattern.

The results indicate that the mere habit of response is slightly more effective in rapidly completing a number-sheet or a simple maze than a combination of habits of response and intention-to-learn-pattern, but, as the number of trials increases, the advantage of the first method lessens.

But when the subjects attack a second problem of a similar nature, both the *speed* and *pattern* groups working under the same directions, *i.e.* to complete the problem as rapidly as possible, it is seen that in the case of the maze those who originally worked with the pattern-intention have a distinct advantage. They worked faster at the beginning and improved rapidly, while the *speed* group had to eliminate many errors and useless movements. This superiority was maintained during the 10 trials.

Those who work in the order maze number-sheet, how-

[10] W. F. Book & L. Norvell, The will to learn, *Ped. Sem.*, 1922, 29, 344.

ever, show comparable results for the numbers. The pattern-intention evidently has no effect in this particular problem where vision dominates in the learning process.

Subsequent repetition of the first problem discloses the fact that the pattern intention persists as demonstrated by the higher time scores of the pattern groups. This suggests that in problems of transfer of learning in acts of skill in which vision is not a dominating factor attention to the pattern itself is one phase of the mental set which the subject must assume to attain a rapid and correct acquisition of the act.

Although similar in design, the two problems which were selected for the learning resulted in different types of learning. The number-sheet required active sensory discrimination and the rapid formation of eye-and-hand coördinations, while the maze involved sensory discrimination and active memorizing.

The learning curves for the individuals and the groups varied with the problem. Those for the number-sheet, both individual and group, were marked primarily by a continuous negative acceleration with a rapid initial descent, followed by a slower descent after the first 2 or 3 trials. When the number-sheet was repeated by Groups I and II this rapid initial descent was lacking.

In most cases, the individual maze-learning curves were marked by extreme variability, that is, the characteristic 'steeples' appeared throughout the curve but were more marked on the second or third trial. These high ascents followed by a rapid fall can be explained in terms of the type of the maze. After the first trial the subject had a general scheme of orientation, *i.e.* the relation of the entrance to the goal, as well as some idea of the path. But so many paths led to a point near the goal that the following trial often resulted in misconceptions. Time was wasted on false moves. Then increased attention, more active memorizing, and discrimination in the seemingly complex situations led to a quicker solution. Exploration became more systematic and productive.

The group curves, too, displayed these 'steeples,' less

marked but, nevertheless, present. An analysis of these same curves for males and females, especially in both the maze series for Groups III and IV, discloses prominent steeples. Particularly inverted are the maze learning curves for the women in Groups I and II. For example, the female curve for Group II jumps from a first trial score of 39.5 sec to a second trial of 109 sec.

Random trial-and-error movements seemed to predominate in the maze learning; but such a term appears inadequate to describe the complete learning process.

A pattern intention is effective in some types of motor learning. But qualitative studies are necessary to determine just how or why such a mental set brought about by specific directions is followed by alterations in the learning process. This intention may direct the learner in such a way that he is more conscious of elements of the learning process and that he makes a more active effort to remember some movements and to eliminate others.

Summary and Conclusions

An essential factor in learning is the attitude to learn. The daily routine of the ordinary individual exposes him to a multitude of unchanging sights and sounds, and yet he can give but a meager report of this constant stimulation. In this situation the 'will to learn' is absent. It was the purpose of this experiment to investigate the effect of intent or mental attitude on the acquisition of two types of problems requiring some degree of motor ability. These problems were a stylus maze and a number-sheet, the patterns of which were identical. The particular intention desired was instilled in the subject by specific instructions. One phase of the general will-to-learn in the mastery of a motor problem would appear to be the attention directed to the pattern itself. Accordingly, the intention selected for study was that mental set in which the subject should devote his attention to the learning of the pattern. What effect would it have on learning one or the other problem? What would be the subsequent effect on learning another similar problem with-

out the intention? Control or *speed* groups and experimental or *pattern* groups, composed of students of college level, were compared.

1. It was found that the pattern intention retarded the speed of learning a maze and a number-sheet.

2. But when an individual was transferred from the number-sheet which had been learned under this intention to learning a maze without the pattern intention his time was materially lowered.

3. Transference to the number-sheet from the maze resulted in improved scores for both the *speed* and the *pattern* groups; but the specific pattern intention had no apparent effect.

4. The effect of the pattern intention was carried over to a repetition of the original problem.

5. A practice series of the maze was more effective in learning the number-sheet than the reverse order.

6. Sex differences in the number-sheet were not significant; but in the maze the women were slightly more variable.

7. The women showed less effect of the pattern instruction than the men.

8. Wide individual variations were characteristic of the maze learning.

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ON THE ABSOLUTE JUDGMENT OF LIFTED WEIGHTS

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Two important forms of the stimulus error, which may operate separately or together, have been distinguished. These are the 'stimulus attitude' and 'absolute impression.' Both are ordinarily involved in common-sense judgments.

Stimulus attitude, the first and more common form of the stimulus error, has been made the object of experimental study with lifted weights by Friedländer,[2] Fernberger,[3] Reid,[4] and Rudisill.[5] These studies have shown that judgments of high precision can be based upon the stimulus attitude.[6] Fernberger, furthermore, has declared that "all of the classical experiments in the field of lifted weights have been performed under this attitude." [7]

The other general form of the stimulus error, and the one with which this paper is concerned, is absolute impression. In absolute impression judgment is made upon a given stimulus without reference to a specific standard. In such cases it has been shown that judgment is based upon the

[1] This study was carried out at the Psychological Laboratory of Princeton University.

[2] H. Friedländer, Die Wahrnehmung der Schwere, *Zsch. f. Psychol.*, 1920, 83, 129–210.

[3] S. W. Fernberger, An experimental study of the 'stimulus error,' this JOURNAL, 1921, 4, 63–76.

[4] A. C. Reid, The effect of varied instruction on the perception of lifted weights, *Amer. J. Psychol.*, 1924, 35, 53–74.

[5] E. S. Rudisill, Constancy of attitude in weight perception, *Amer. J. Psychol.*, 1925, 36, 562–587.

[6] Reid (*op. cit.*, 74) found that the stimulus attitude 'gives the most accurate results.' Rudisill (*op. cit.*, 587) found that 'the stimulus attitude yielded the highest precision of judgment.' Fernberger (*op. cit.*, 76) found that 'the coefficients of precision for the psychometric functions of both the less and greater judgments are very similar for all three instructions' (pressure, kinæsthetic, and stimulus instructions).

[7] Fernberger, *op. cit.*, 76.

relationship which exists between the given stimulus and a series of stimuli of a more or less definite range.[8] The presence of absolute impression has been indicated in at least seven sensory fields.[9] Its influence upon judgments of lifted weights was first clearly pointed out by Martin and Müller,[10] who explained certain characteristics in the distribution of judgments upon the basis of absolute impression. They also found evidence for its existence in this fact: in experiments involving the second time order (*i.e.* variable-standard), the observers reported a tendency to judge the variable in terms of the whole series of weights before the standard had been lifted. The absolute factor in lifted weight experiments has also been reported by Kinnaman [11] and Fröbes.[12]

Recently, Hulin and Frazier [13] have made a direct experimental attack on the problem of absolute impression in lifted weights. They set up for the observer what they considered to be the simplest situation for its development, namely, the presentation of one initial standard followed by two successive comparison stimuli. This study showed 'a significant similarity between the psychometric functions of the test and the normal series' [14] for two of the three observers. It is this method which is used and extended in the present study.

In absolute impression a knowledge of the range of stimuli is logically implied as the necessary basis for judgment. The development of the basis is rapid, as shown by Truman

[8] E. G. Wever & K. E. Zener, The method of absolute judgment in psychophysics, *Psychol. Rev.*, 1928, 35, 466–493.

[9] E. B. Titchener, *Experimental Psychology, Instructor's Manual, Quantitative*, 1905, 304, note 5. See also *ibid.*, lxiii–lxvii, and *idem.*, *A Text-Book of Psychology*, 1909, 312 f, 398, 533, 536.

[10] L. J. Martin & G. E. Müller, *Zur Analyse der Unterschiedsempfindlichkeit*, 1899 (Leipzig), 43 ff.

[11] A. J. Kinnaman, A comparison of judgments for weights lifted with the hand and foot, *Amer. J. Psychol.*, 1900–01, 12, 250 f.

[12] J. Fröbes, Ein Beitrag über die sogenannten Vergleichungen übermerklicher Empfindungsunterschiede, *Zsch. f. Psychol.*, 1904, 36, 257, 265, 266 f.

[13] W. S. Hulin & L. R. Frazier, Two comparison stimuli with one initial standard in lifted-weights, *Amer. J. Psychol.*, 1928, 40, 626–627.

[14] *Ibid.*, 627.

and Wever [15] for pitch and by Wever and Zener [16] for lifted weights.

Truman and Wever presented a standard tone followed by a series of five comparison tones upon which 50 successive judgments were made. Two procedures were used. In one, the standard was equal to the middlemost comparison tone. In the other, the standard was equal to the lowest tone of the comparison series. In both cases it was found that judgments of pitch ('high,' 'low,' and 'equal') were distributed fairly symmetrically about the midpoint of the comparison series. This indicated that the basis of judgment was absolute impression, that is to say, dependent upon the placement of the series as a whole.

In their study with lifted weights Wever and Zener similarly compared the psychometric curves normally obtained by the method of constant stimuli with those obtained by the method of absolute judgment, and found that the curves were 'significantly alike.' [17]

As stated above, the present study aimed to extend the method of absolute judgment originated by Hulin and Frazier.[18] Their procedure was repeated with five observers, and, furthermore, in a second test series, it was extended in that the initial standard was followed by seven comparison weights. Separate limens were likewise calculated for the seven comparison positions. Prior to the test series, the limens of each observer had been determined in the normal manner (in terms of relative judgments) by the method of constant stimuli.

The Method of Experimentation

Five observers were employed: Professor W. S. Hulin (H), Dr. E. G. Wever (W), Dr. K. E. Zener (Z), Dr. C. W. Bray

[15] S. R. Truman & E. G. Wever, The judgment of pitch as a function of the series, *Univ. Calif. Publ. Psychol.*, 1928, 3, 215–223.

[16] E. G. Wever & K. E. Zener, The method of absolute judgment in psychophysics, *Psychol. Rev.*, 1928, 35, 466–493.

[17] *Ibid.*, 493. This article contains a general history of the absolute method in psychophysics.

[18] Hulin & Frazier, *op. cit.*, 626–627.

(B), and Dr. J. J. Gibson (G). All, except G, had served in other lifted weight experiments.

The stimuli were fiber weights, similar to the kind described by Fernberger.[19] In all series the standard was 100 grams. The comparison weights were 84, 88, 92, 96, 100, 104, 108 grams. In every case the standard was presented first and was followed by one or more comparison weights. The order of presentation was so arranged as to avoid contrast-effect.[20] The weights were placed upon a revolving-top table, which was rotated by the experimenter. The observer's right arm rested upon a padded arm-rest and his right hand extended palm downwards. With a simple downward movement the hand came into a convenient position to grasp one of the weights. In this way the space error was eliminated. A screen prevented the observer from seeing the experimenter and apparatus.

The experiment was divided into three series, each observer undergoing them in the same order. These series were: (1) the normal series, in which the initial standard was followed by one comparison weight, (2) test series *A*, in which the initial standard was followed by two comparison weights, and (3) test series *B*, in which the initial standard was followed by seven comparison weights.

The following written instructions were given.

(1) *For the normal series.* "You will be presented with a series of weights in pairs, first with a standard and then with a comparison weight. You are to make a judgment of 'greater,' 'equal,' or 'less,' according as the second stimulus is greater, equal to, or less than the first stimulus in weight. The category 'equal' is to be restricted to cases of positive perceptions of equality. In case of failure to make a judgment report 'failure,' in which case the stimulus will be presented later in the series. You are to assume the stimulus or objective attitude."

(2) *For test series A.* "You will be presented with a

[19] S. W. Fernberger, A new form of stimuli for lifted weight experiments, *Amer. J. Psychol.*, 1920, 31, 147–151.

[20] S. W. Fernberger, Interdependence of judgments within the series for the method of constant stimuli, this JOURNAL, 1920, 3, 126–150.

standard and then with a comparison weight upon which you are to make a judgment of 'greater,' 'equal,' or 'less.' Then, as soon as you have made this judgment, you will be presented immediately with a second comparison weight which you will likewise judge in terms of the initial standard. In case of failure to report either or both comparison weights report 'failure.' You are to maintain the stimulus attitude."

(3) *For test series B.* "You will be presented with a standard weight and then in turn with seven comparison weights, each of which you are to judge as soon as it appears in terms of the initial standard. When you have judged one of the comparison weights the next will be presented. You are to maintain the stimulus attitude."

It may be seen from these instructions that the observer was told to judge all comparison weights in terms of the initial standard and to maintain the stimulus attitude.

For each observer in the normal series 400 judgments were made on every comparison weight. In test series *A*, 100 judgments were made on every comparison weight in each comparison position, that is to say, every comparison weight was judged 100 times as the first comparison and 100 as the second comparison. In test series *B*, every comparison weight was judged 100 times in each of the seven comparison positions. Limens were calculated for the normal series and separately for each comparison position of the test series, in accordance with the $\Phi(\gamma)$ hypothesis by means of Urban's tables.[21]

Quantitative Results

The calculated results are shown numerically in Tables I–V and graphically (for series *B*) in Figs. I–V.[22]

A single table gives the complete results for one observer. Each table is similarly constructed. In the first column there are given the names of the series, and, in the case of the test series, the several comparison positions.

[21] F. M. Urban, *Die Praxis der Konstanzmethode*, 1912 (Leipzig), pp. 26. Urban's tables for the constant process and Rich's checking tables are given in W. Brown & G. H. Thomson, *The essentials of mental measurement*, 1925, 202–203, 206–209.

[22] A complete record of all judgments with their distributions is contained in Appendix I, which is deposited in the Library of Princeton University.

TABLE I

OBSERVER B

Series		h_1	h_2	S_1	S_2	I.U.	P.S.E.
Normal series		0.083	0.088	94.26	98.27	4.01	96.31
Test series *A*	1st comp.	0.075	0.074	94.35	97.07	2.72	95.70
	2d comp.	0.066	0.066	93.51	96.55	3.04	95.03
Test series *B*	1st comp.	0.088	0.088	95.01	95.44	0.43	95.22
	2d comp.	0.086	0.086	94.73	94.77	0.04	94.75
	3d comp.	0.072	0.074	95.99	96.14	0.14	96.06
	4th comp.	0.086	0.086	96.60	96.64	0.04	96.62
	5th comp.	0.083	0.081	96.71	96.80	0.09	96.76
	6th comp.	0.087	0.086	95.83	95.86	0.04	95.84
	7th comp.	0.096	0.098	94.49	94.67	0.18	94.58

TABLE II

OBSERVER G

Series		h_1	h_2	S_1	S_2	I.U.	P.S.E.
Normal series		0.100	0.102	94.58	94.82	0.24	94.70
Test series *A*	1st comp.	0.100	0.102	91.41	93.43	2.01	92.43
	2d comp.	0.100	0.109	91.12	92.95	1.82	92.07
Test series *B*	1st comp.	0.093	0.095	94.22	94.54	0.31	94.38
	2d comp.	0.074	0.075	95.36	95.20	0.16	95.28
	3d comp.	0.100	0.099	94.53	94.57	0.04	94.55
	4th comp.	0.094	0.094	93.50	93.57	0.08	93.54
	5th comp.	0.099	0.107	95.27	93.75	1.51	94.48
	6th comp.	0.098	0.098	94.20	94.32	0.12	94.26
	7th comp.	0.091	0.091	92.91	92.91	0.0	92.91

TABLE III

OBSERVER H

Series		h_1	h_2	S_1	S_2	I.U.	P.S.E.
Normal series		0.086	0.093	97.87	101.76	3.90	99.89
Test series *A*	1st comp.	0.096	0.099	100.42	100.77	0.35	100.60
	2d comp.	0.081	0.082	100.92	100.97	0.05	100.95
Test series *B*	1st comp.	0.095	0.095	99.80	99.80	0.0	99.80
	2d comp.	0.093	0.093	99.59	99.59	0.0	99.59
	3d comp.	0.093	0.093	100.77	100.77	0.0	100.77
	4th comp.	0.110	0.110	98.93	98.93	0.0	98.93
	5th comp.	0.105	0.105	99.50	99.50	0.0	99.50
	6th comp.	0.111	0.111	100.26	100.26	0.0	100.26
	7th comp.	0.089	0.089	100.88	100.88	0.0	100.88

TABLE IV

OBSERVER W

Series		h_1	h_2	S_1	S_2	I.U.	P.S.E.
Normal series		0.078	0.078	94.74	96.86	2.12	95.79
Test series *A*	1st comp.	0.082	0.078	93.60	97.46	3.86	95.48
	2d comp.	0.084	0.070	92.50	98.46	5.97	95.21
Test series *B*	1st comp.	0.076	0.073	92.87	97.38	4.52	95.07
	2d comp.	0.077	0.082	92.12	96.47	4.35	94.36
	3d comp.	0.073	0.073	90.69	96.92	6.24	93.80
	4th comp.	0.074	0.074	90.73	96.71	5.99	93.72
	5th comp.	0.077	0.080	91.03	96.07	5.04	93.60
	6th comp.	0.078	0.077	90.67	96.92	6.25	93.76
	7th comp.	0.068	0.078	89.53	95.37	5.84	92.67

TABLE V

OBSERVER Z

Series		h_1	h_2	S_1	S_2	I.U.	P.S.E.
Normal series		0.102	0.097	94.46	96.03	1.58	95.22
Test series *A*	1st comp.	0.106	0.104	91.47	96.03	4.56	93.73
	2d comp.	0.082	0.093	92.12	97.13	5.01	94.78
Test series *B*	1st comp.	0.104	0.111	94.41	95.67	1.26	95.06
	2d comp.	0.102	0.099	95.55	96.18	0.63	95.86
	3d comp.	0.110	0.112	96.03	97.20	1.17	96.62
	4th comp.	0.102	0.102	95.68	96.93	1.25	96.30
	5th comp.	0.103	0.104	96.15	97.19	1.04	96.67
	6th comp.	0.100	0.108	95.93	96.94	1.01	96.45
	7th comp.	0.085	0.099	96.07	96.93	0.87	96.53

The second and third columns contain the values of the coefficients of precision of the less (h_1) and the greater (h_2) judgments respectively. The fourth and fifth columns contain the values of the lower (S_1) and the upper (S_2) limens respectively. The sixth column contains the values of the intervals of uncertainty (I.U.), and the seventh column contains the values of the points of subjective equality (P.S.E.).

The charts present the results for all observers in test series *B* alone. In all charts the horizontal axes represent the seven comparison positions. The vertical axes represent in Figs. I and II the coefficients of precision of the less and the greater judgments respectively, in Figs. III and IV the lower and the upper limens respectively, and in Fig. V the points of subjective equality.

Discussion of Results

The range of variability shown for the various comparison positions in the test series is on the order of that generally found in lifted weight experiments. That is to say, the

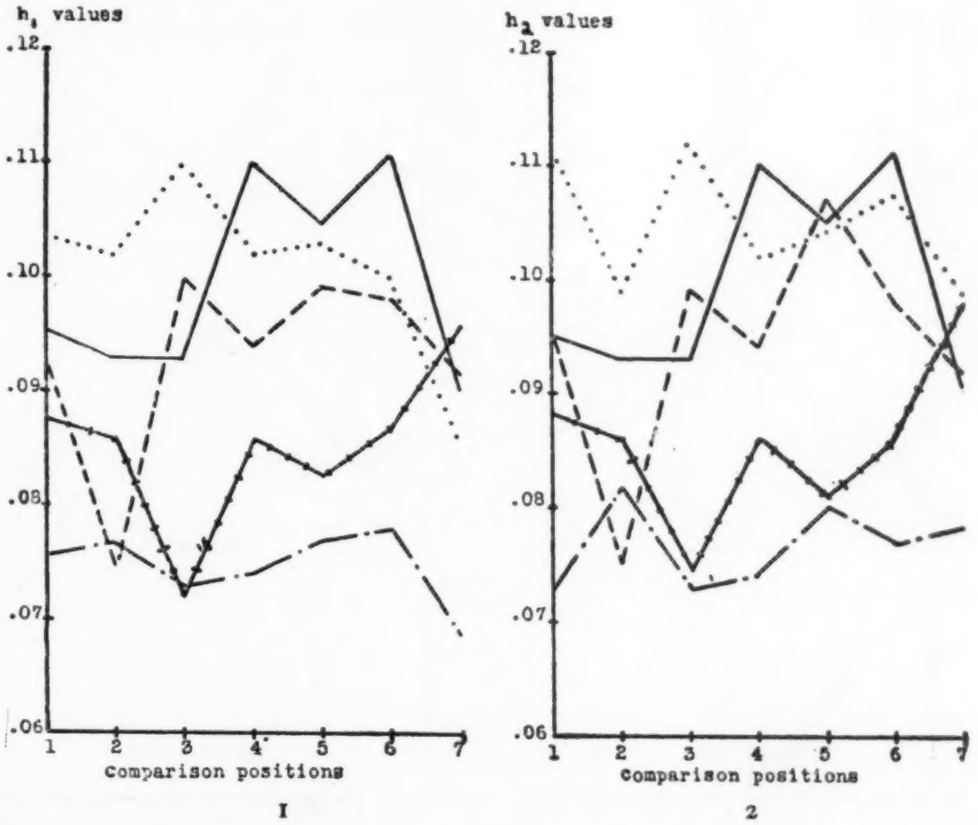

Fig. 1. Values of h_1 for all observers in test series *B*.
Fig. 2. Values of h_2 for all observers in test series *B*.

variability from one comparison position to the next is no greater than the variability in a normal (*i.e.* relative) series under a given instruction from one day to the next.[23] The test methods employed, then, are as suitable for lifted weight measurements as the traditional method of relative judgments.

In the case of Obs. H, although his limens are high in all series, the coefficients of precision are similar to those of the other observers. In explanation of his results, H gave the following report; "In my previous training with lifted weights I developed two special criteria which were effective

[23] *Cf.*, *e.g.*, S. W. Fernberger, An experimental study of the 'stimulus error,' this Journal, 1921, 4, 71, Tables I–III, and E. S. Rudisill, Constancy of attitude in weight perception, *Amer. J. Psychol.*, 1925, 36, 580, Tables V–VIII.

in the present experiment. First, I had found that if I assumed a wholly passive attitude before judging the standard, I then assumed a very strained attitude after the standard in order to exert the same amount of effort in lifting the com-

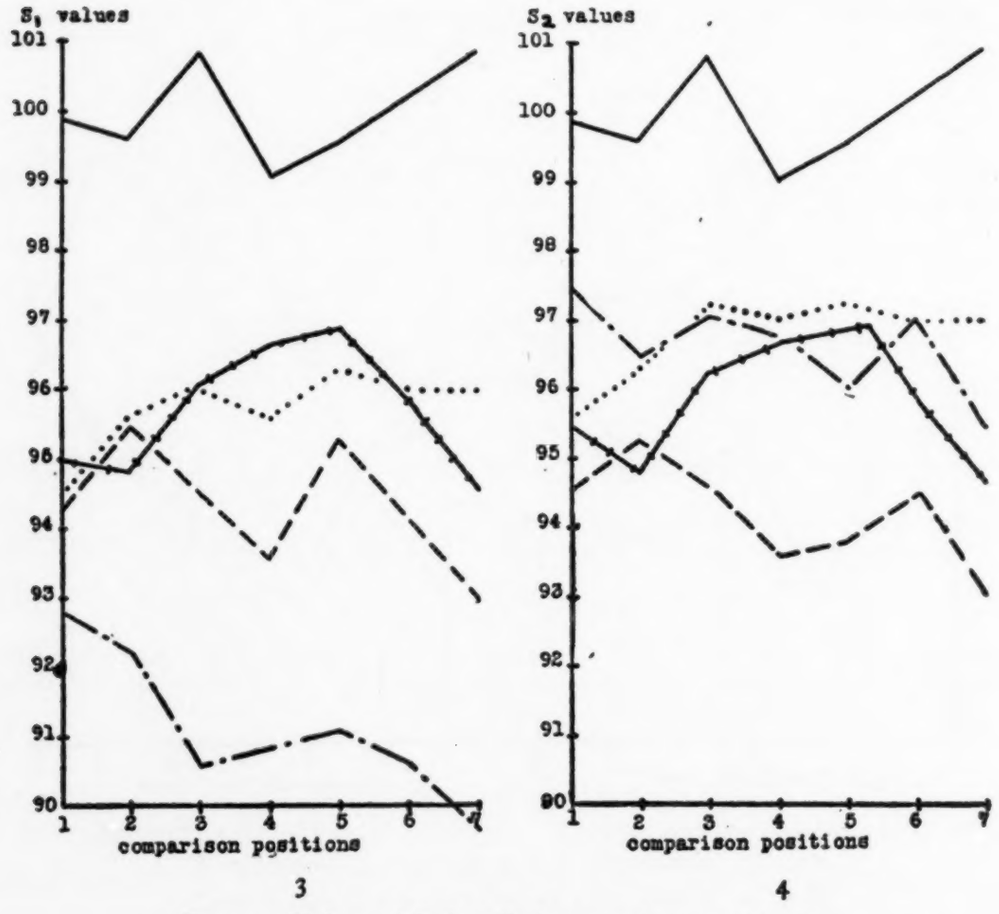

FIG. 3. Values of S_1 for all observers in test series *B*.
FIG. 4. Values of S_2 for all observers in test series *B*.

parison weight. The result of this constraint had been that the comparison weight seemed more often heavier. But in the present experiment I found that with a constant tension for both the standard and comparison the existential intensity of the comparison presentations was much more frequently 'less' than 'greater.' Secondly, since I knew there were only two objectively heavier weights I became very critical and cautious in giving judgments of 'greater.'"

Significant points in the reports of the observers may be summarized thus:

In the normal series, two observers (W and Z) reported the presence of an absolute factor, a tendency to judge the comparison weight in terms of the series.

In test series *A*, four observers (B, G, W, and Z) reported that they were unable to compare the second comparison weight directly with the standard.

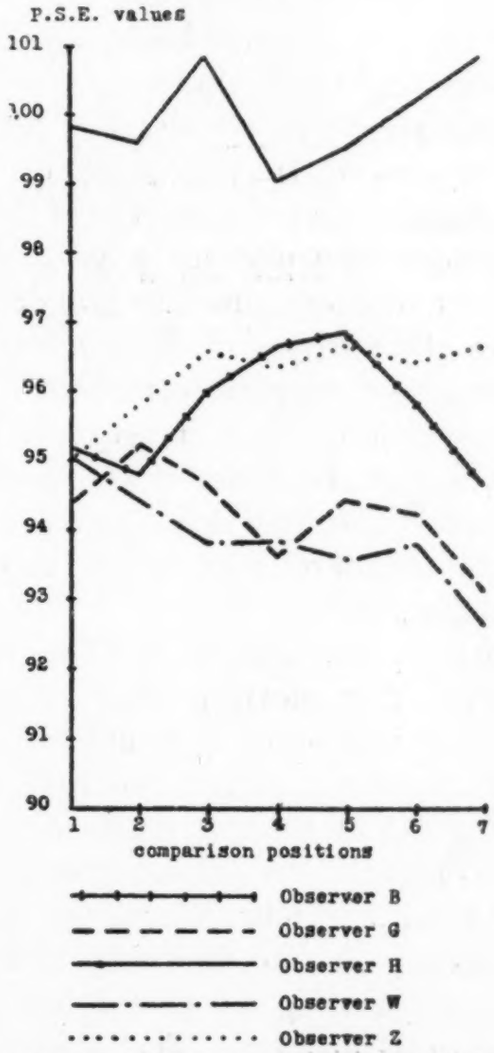

FIG. 5. Values of P.S.E. for all observers in test series *B*.

Obs. G reported: "The memory image of the standard is completely gone by the time of the lifting of the second comparison weight. The judging goes on at a verbal level, hardly rising to consciousness."

Obs. W reported: "When the standard appears I judge it in relation to the series as a whole, and then I relate the oncoming comparison weights to it."

Obs. Z reported: "The first judgment sets a certain level, as it were, and the second judgment is above or below that level."

In test series *B*, three observers (B, H, and G) reported that the standard persisted for the first two judgments, after which judgments were upon an absolute basis. Towards the end of the experiment these observers reported that all judgments were upon an absolute basis, and that the standard was playing a very slight rôle, if any.

Obs. W reported: "The standard is judged absolutely, *i.e.* placed in a general subjective series. The standard usually seemed heavier than the middle of the series."

Obs. Z reported: "I build up a general notion of the series as a whole, and every time the standard is lifted I get an impression of the position of the standard in the series. Subsequent comparison weights seem higher or lower in the series than the standard. My imagery is kinæsthetic not visual. The notion of the series is transformed every time I lift the standard. The first judgments are definitely more a function of the standard than the last; the effectiveness of the standard dies out."

The similarity in the reports of Obs. W and Z might lead one to expect that plotting their points of subjective equality (P.S.E.) in test series *B* would yield a similar form of curve. Such, however, is not the case, as is shown in Fig. V. The P.S.E.s of Obs. Z increase rapidly from the first to the third comparison positions, after which they remain constant. The P.S.E.s of Obs. W, on the other hand, show a more or less steady decline from the first to the seventh comparison position, ending 3.6 grams below the value for the first comparison position. The greatest similarity is between the P.S.E. curves of Obs. W and G. The P.S.E. curve of Obs. B is similar to that of Obs. Z until the fifth comparison position, after which B's curve shows a precipitate decline. The P.S.E. curve of Obs. H varies throughout within one gram of 100 grams, without exhibiting a specific tendency.

Wever and Zener [24] found that for each observer the

[24] E. G. Wever & K. E. Zener, The method of absolute judgment in psychophysics, *Psychol. Rev.*, 1928, 35, 486–487.

P.S.E. was lower in the absolute than in the relative series. This downward shift they explained as due to the fact that the midpoint of the absolute series (96 grams) was lower than the standard of the relative series (100 grams). Our results partially bear out this finding. In test series *A* the P.S.E.s of both comparison positions are lower than the P.S.E. of the normal series, in the case of four of the five observers (all except Obs. H). In test series *B* the P.S.E. of the first comparison position is lower than in the normal series for all observers, but for the remaining comparison positions this does not always hold. Indeed in the case of Obs. Z, all the remaining P.S.E.s are higher than in the normal series.

The various types of curve exhibited by the several observers indicate the complexity of the factors operating in absolute impression. That these factors are largely below the level of consciousness is shown by the fact, among other things, that observers giving similar reports as to the method of judgment yield dissimilar results. It was also found that no observer knew in which direction his limens were varying in the test series. These facts would indicate that introspection is of little value in interpreting this kind of work.

Summary

Absolute judgment of lifted weights has been tested by presenting a standard followed (*A*) by two successive comparison stimuli, and (*B*) by seven successive comparison stimuli. Separate limens were calculated for the several successive comparison positions.

The limens (absolute) of the comparison positions, irrespective of the temporal distance from the standard, are similar to the normal limens (relative). The variability of the limens from one comparison position to the next is on the order of that generally found in lifted weight experiments. The test methods employed, then, are as suitable for lifted weight measurements as the traditional methods of relative judgments. Individual differences as to methods and tendencies of judgment were found to be large.

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DURATION OF THE EFFECTS OF POST-HYPNOTIC SUGGESTION

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One of the important but neglected problems of hypnotism is the duration of the influence of a suggestion given in the trance to apply to subsequent waking behavior. Neglect is regrettable both because of the theoretical importance of the subject and because post-hypnotic suggestion has been used from time to time in therapeutic treatment of undesirable mental conditions. This present study[1] is the first attempt[2] at a quantitative determination of the answers to the following questions: How long does the effect of post-hypnotic suggestion last? What is the typical curve of its decrease with time? and what factors tend to affect its permanence?

The post-hypnotic suggestion used in this experiment was originated by Milton H. Erickson, a student at the University of Wisconsin. It involves a specific variation in the rate of respiration. The subject is instructed that when he reads the even-numbered pages of a given book he will breathe twice as fast as usual and when he reads the odd-numbered pages he will breathe twice as slowly, or half as fast, as usual. For purposes of comparison, these instructions are given to one group of subjects as post-hypnotic suggestions and to the rest as simple waking instructions. It is evident that this procedure affords a means of quantitative determination of the effect of the suggestion at any

[1] The first to be planned and the fourth published of a series of studies in hypnotism carried out in the Psychological Laboratory of the University of Wisconsin. The writer wishes to express her indebtedness and gratitude to Professor Clark L. Hull for constant advice and criticism during the course of the investigation.

[2] Except for a study undertaken by Raymond H. Ludden (*Studies in the permanence of post-hypnotic suggestion*, 1925, master's thesis, Univ. of Wis. Library). L. used in general the method followed in this experiment; but his method was seriously at fault in several respects and his results inconclusive.

time. It has two defects. One is the fact that two variables may be involved in the measured influence of the suggestion at any time; the ability to control the respiration and the endeavor to do so. The other and more important defect is the fact that a ratio greater than the one suggested may be an index of greater influence of the suggestion, or, on the other hand, of a forgetting of its quantitative aspect. The writer believes, however, that in general the context of the situation indicates which interpretation should be followed in a given case.

Thirteen subjects were used, all students at the University of Wisconsin. None of them had any interest in the problem being studied, and all precautions were taken to prevent their realization of the significance of the experiment and of the part they played in it.

The Ss were divided into two groups. Group I was composed of hypnotic subjects, to whom the suggestion was given in the trance. Most of these Ss had been trained by the experimenter herself. All had been hypnotized by her at least twice before the experiment began. All had been used, or were used during the course of this study, as subjects in other hypnotic projects. Each habitually went into deep trance, showing characteristic phenomena and waking amnesia for all trance events. The experimenter is convinced that in no case was there a doubt that the trance was genuine.

The Ss of Group II were not hypnotized for this experiment. Only one of them, CL, had ever been in a trance and her trance was light and difficult to induce. All were kept in ignorance of the purpose of the experiment, and did not even know that they were acting as controls to trance subjects.

The book used throughout the experiment was Edna St. Vincent Millay's *The harp weaver and other poems* (Harper, New York, 1927). The series of sonnets that begins on page 49 formed the reading-material for all subjects. As these sonnets are printed one on a page, they provided material in small equal divisions. Their homogeneity of tone, content, and rhythm, together with the fact that the Ss without exception found them deeply boring, provided against an emotional stimulation which might have affected the breathing rate.

The respiration-record was taken by means of a thoracic pneumograph connected by rubber tubing with a light pointer writing on a Stoelting kymograph. Vertically in line with this marker were two other, electro-magnetic, markers, one for the experimenter's signal and the other connected in circuit with a pendulum clock for recording five-sec intervals on the smoked paper.

The following procedure was used for all the Ss of Group I.

S was brought into the experimental room and hypnotized by the method to which he was accustomed; visual fixation followed by suggestions of relaxation and deep sleep. He was then seated with his back to the apparatus and told that when sound asleep he would signal by raising his right hand. This signal was familiar to all the Ss. After it was given, S was instructed to continue sleeping deeply and given a specific suggestion in the following words.

"I am going to give you a book, and you are going to open your eyes and read it to yourself; and while you are reading on the odd-numbered pages you are going to breathe twice as slowly as usual, and while you are reading on the even-numbered pages you are going to breathe twice as fast as usual, so that on the even-numbered pages you will be breathing four times as fast as on the odd. Do you understand? And you are going to breathe this way whenever you read this particular book, whether you are awake or whether you are asleep, for always and always and always: twice as fast as usual on the even pages, and twice as slow as usual on the odd pages. You're going to do this, but you won't remember why you do it. You won't notice anything unusual about your breathing, and you won't know what the experiment is about; you'll think it has something to do with measuring your emotions while you read."

The operator then attached the pneumograph, gave S the book, and told him to read. As he read, the operator watched his eye-movements and pressed the signal-key at each change from one page to another. During the reading the experimenter urged, as it seemed necessary, 'faster,' 'slower,' or 'breathe more smoothly,' until it became evident that S had achieved the most exact obedience of which he was capable. After half-a-dozen more pages had been read without further suggestion, making a total of at least fourteen, the book and pneumograph were removed, amnesia again suggested, and S wakened.

S was at once taken to another room where for fifteen minutes his attention was occupied in miscellaneous conversation. The experimenter then led him back, explaining that his emotions were to be tested. As E adjusted the pneumograph, she tested S's amnesia by asking casually whether he had ever worn a pneumograph before. Satisfied that S had forgotten the events of the trance, E gave him the book and asked him to read until instructed to stop. For fourteen pages he read without interruption, while the experimenter took a respiration-record in the way described above.

This waking test was repeated the next day and thereafter at intervals of one or two weeks, with some cases at longer intervals, all barring irregularities from university vacations. The time of day at which the testing occurred never varied by more than an hour. The experimenter herself was always present. The same fourteen pages were always read and in the same order. All conditions, therefore, were kept as constant as possible. The trance condition never again occurred during the experiment; although, as has been said, the Ss were sometimes hypnotized in other experiments.

The schedule outlined above was followed for subjects EL, DC, LS, EC, and HG. For the remaining trance subjects (Group Ib and Group Ic) the intervals between tests were changed. MB was tested the day of the suggestion, and again 1 day, 8 days, and 66 days after it was given; and KE the day of the suggestion, 1 day later, and 60 days later. The purpose of this variation was to test whether practice was a factor in maintaining the influence of the suggestion. IC was tested practically every day for 12 days.

In Group II the procedure was in all respects similar to that followed for Group I, except that the Ss were never thrown into a trance.

The instructions given were the same, except that the commands relative to amnesia were omitted, and it was emphasized that the instructions would never be repeated. During the first practice (as with the trance subjects) E gave suggestions to improve the performance. The normal Ss were then given a test after fifteen minutes to parallel the schedule used with Group I. They were all tested at the

intervals used for Group Ia, with the exception of CL, who (like IC) was tested daily. Although some of the Ss of Group II occasionally asked questions on details of the instructions, E was careful to tell them nothing after the first occasion.

Fig. 1 shows a smoked-paper tracing of a typical record made by a trance subject on whom the suggestion still retained considerable influence. From such records as this the

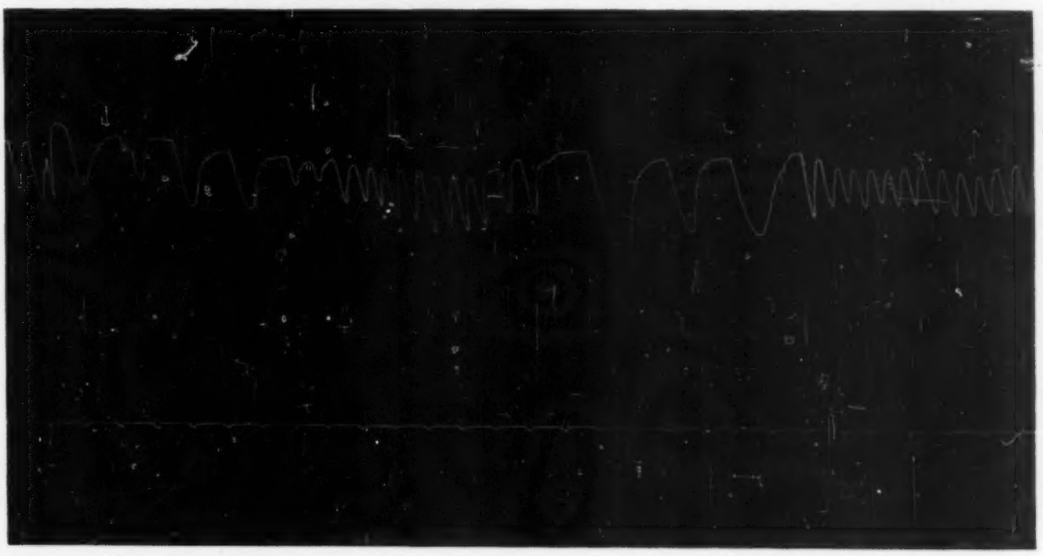

FIG. 1. Section of typical respiration record. Subj. EC, 90 days after giving suggestion. Ratio of rate on even pages to rate on odd = 3.1. Upper line, breathing; middle line, signal marking change from page to page; bottom line, time in 5-sec intervals.

effect of the suggestion at each period of testing was computed. The number of complete breaths on all the odd-numbered pages was counted, and divided by the number of seconds spent in reading, to obtain an average breathing-rate. The same process gave the breathing-rate for the even pages. From these two averages the ratio of the rates for even and odd pages was obtained. This ratio was taken as the index of the strength of the suggestion. For purposes of convenience, the first term of the ratio was always expressed in decimal form, and the second term, 1, was disregarded.[3]

Of the eight trance subjects used in this experiment, two

[3] For a statement of difficulties encountered in making computations from these records, and an explanation of how they were met, see E. R. Kellogg, A study in the duration of the effects of post-hypnotic suggestion as contrasted with the influence of similar instructions given to waking subjects (Thesis, Univ. of Wis. Library), pp. 13–14.

showed slight flaws in amnesia. LS remembered toward the end of the study what suggestion had been given; although, as she asserts, she made no effort to carry it out. HG, halfway through the experiment, became aware that her breathing varied from page to page; although how or why she did not know. The other six Ss were in complete ignorance throughout the experiment. None noticed any change in breathing, or guessed that a post-hypnotic suggestion was being tested.

The mean ratios between the respiration rates on odd and even pages for all Ss at each time of testing are arranged in tabular form in Tables I and II. Table I compares the

TABLE I

RATIOS OF RATE-ON-EVEN TO RATE-ON-ODD PAGES (GROUPS Ia AND IIa)

Time after giving suggestion	Ratios for Group Ia					Ratios for Group IIa			
	EL	DC	EC	LS	HG	AA	DL	EJ	GS
(Practice)	6.4	2.9	3.2	1.7	3.2	3.76	3.97	4.74	3.09
15 min	4.6	1.84	4	2.65	3.2	3.76	9.75	8.64	3.27
1 day	4.8	2.0	6.5	1.8	3.7	4.0	10.5	9.73	3.58
8 days	3.1	1.6	5.1	1.4	3.86		16.5	14.34	4.1
9						4.1			
15	4.6	1.5	4.3	1.2	2.44	5.04	14.94	15.2	4.15
22	2.14	1.2	2.7	1.4	2.4	5.44		13.0	
29				1.56	2.9				3.26
32	1.5								
36		1.38	3.7	1.4	3.06				
43	1.3				2.91				
50			3.35		1.63	5.95	16.0		
55								14.1	
57	1.15	1.4				4.33	14.48		3.56
64			4.0				15.6	13.3	4.14
66						4.16			
73									3.77
77			3.5						
78				1.2					
85					2.24				
90			3.1						
99					3.03				

ratios of Groups Ia and IIa. A study of this table brings out the following facts.

1. There is great variability among the Ss in their response to the suggestion.

2. The trance subjects on their first independent performance tend to accomplish less than the ratio asked of them, whereas the normals tend to exceed their instructions.

3. The performance of the normal subjects shows no loss in the power of the suggestion with time. In all cases, at the last time of testing, nine or ten weeks after the instructions were given, the response is greater than at the first test.

4. The performances of the trance subjects, on the other hand, show a loss in the force of the suggestion with time, the ratio attained at the last test being in all cases lower than at the first waking test.

5. There is a general tendency, in the case of the trance subjects, for a good initial performance to be associated with a relatively high level throughout.

6. The records of both trance and normal subjects show many irregular fluctuations. These may represent fluctuations in the actual force of the suggestion or in the ability to control the breath. The latter might readily be influenced by fatigue, hunger, or other physical factors.

In order to study the relative changes in the power of the suggestion the ratios attained by each subject were changed to percentages of his initial independent performance. The ratio 1: 1 was taken as 0 percent, the ratio of the first waking test as 100 percent. Therefore the percentages were computed by the formula

$$X_n = \frac{R_n - 1}{R_1 - 1}.$$

The values obtained in this way are used as ordinates in the graphs of Fig. 2 and Fig. 3. The former shows the performances of the subjects of Group Ia, the latter of Group IIa. By taking the mean of these values at regular intervals, composite curves are obtained for each group. The two composite curves are compared in Fig. 4.

Study of these figures reveals the following facts.

1. Three out of the five curves in Fig. 2 have their highest peak 24 hours after the giving of the suggestion, and the composite curve has a maximal height at this point. This seems to indicate that on the first waking test, fifteen minutes after the trance, the novelty of the situation interferes

with the performance, and that this distortion is removed by the effect of the first practice.

2. During the first three weeks, the curves of the trance subjects (Fig. 2) show a general tendency to fall rapidly;

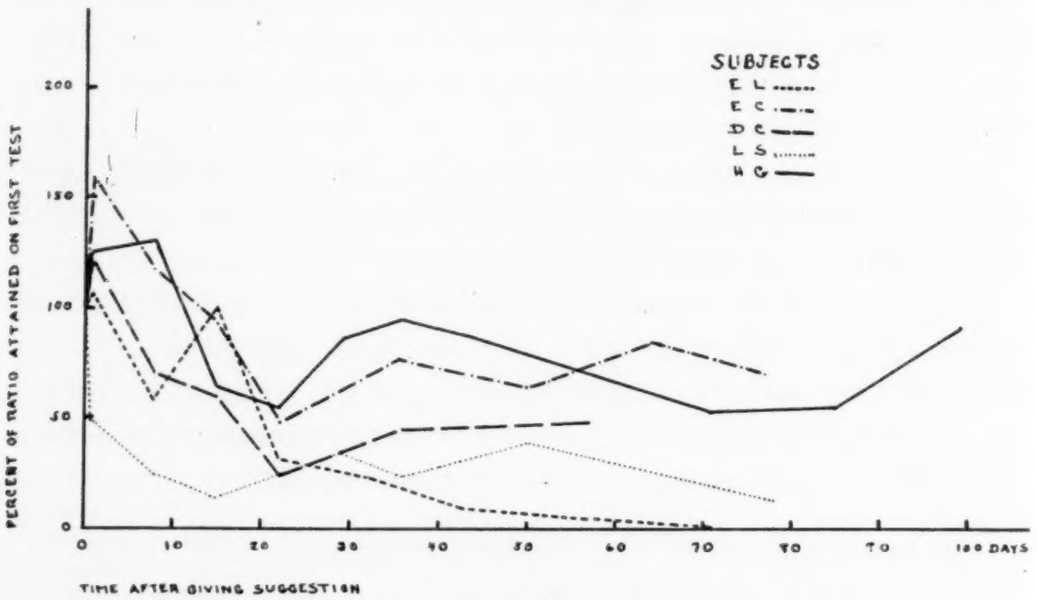

FIG. 2. Group Ia.

although in the cases of EC and EL with gross fluctuations. This rapid decrease is shown clearly in the composite curve, whose lowest point occurs at the end of three weeks at 37 percent.

3. The normal curves, on the other hand, have a general tendency to rise at first, attaining at fifteen days after the suggestion 139 percent to 185 percent of the original performance, with a mean at 157 percent. There is, moreover, less consistency in their shape than in that of the trance subjects, and the time of the peak has the appearance of being determined more by chance than by a general tendency.

4. In the case of the trance subjects, there is a general tendency for the curve to flatten out, though rising slightly, after three weeks. The only subject whose curve does not follow this pattern is EL. Her curve falls gradually and smoothly from this point till it reaches an approximate zero at 71 days.

5. The shape of the normal curve after the first three

weeks is influenced by the fact that Christmas vacation necessitated a period of four weeks in which the effect of the suggestion was not tested. It is interesting to note that all four subjects show a rise of almost the same slope over this period. As the subjects were in different stages of the experi-

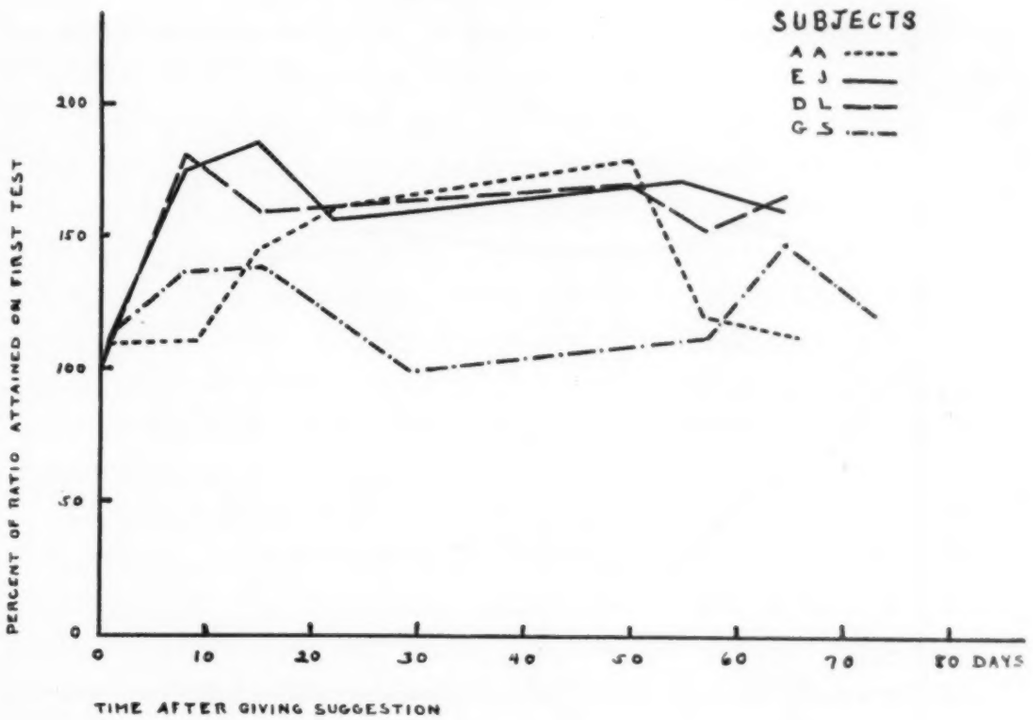

FIG. 3. Group IIa.

ment when this vacation occurred, the shape of the composite curve is distorted, and lends itself to no obvious interpretation. Nevertheless, it may, in the opinion of the writer, be justifiably assumed that, if the testing had continued to occur at regular intervals, each curve would have remained fairly flat after its initial rise, though falling slightly.

Table II shows the results obtained with the two subjects of Group Ic who were given a long period without testing between their third and fourth waking tests. In both cases the ratio decreases. To these may be added the record of Subj. HG, which, as seen in Table I and Fig. 2, shows a decided decrease in ratio over the four weeks of vacation which intervened between her eighth and ninth waking tests. Comparing these with the normal performances discussed imme-

diately above, one observes a significant difference between the trance and normal groups. It would appear that a period without practice tends to revive the force of instructions given in the waking state, but to lessen the strength of a post-hypnotic suggestion.

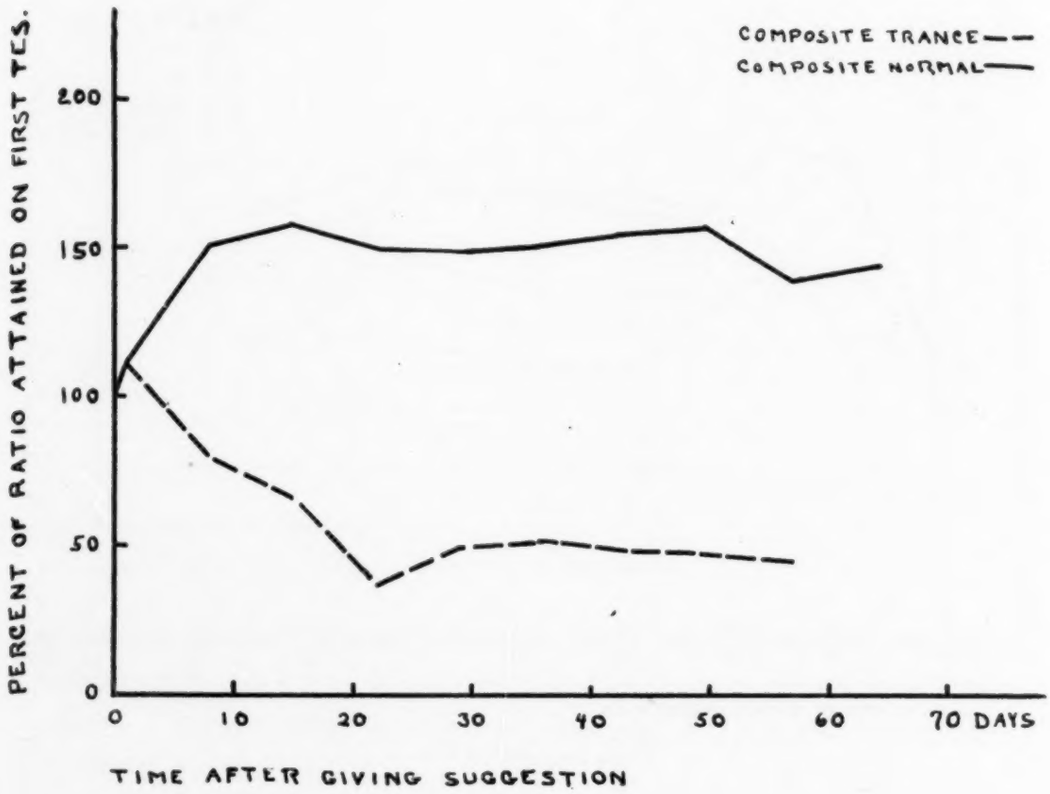

FIG. 4.

TABLE II

THE EFFECTS OF FREQUENT PRACTICE AND OF LONG PERIODS WITHOUT PRACTICE ON THE RATIOS ATTAINED AT EACH TRIAL. GROUPS I*b*, I*c* AND II*b*

Time after giving suggestion	Ratios of Group Ib IC	Ratios of Group IIb CL	Time after giving suggestion	Ratios of Group Ic MB	KE
(Practice)	4.77	4.33	(Practice)	4.52	2.4
15 min	2.79	4.33	15 min	2.96	2.24
1 day	3.03	7.56	1 day	2.26	2.2
2 days	1.51	7.45	8 days	4.23	
3	2.13	7.87	60		1.48
4		9.24	66	2.12	
5	1.7				
6		11.91			
7	2.23	10.12			
8	1.89	10.78			
9	2.07	8.9			
10	1.95	9.25			
11		8.18			
12	2.48				

In Table II are also listed the mean ratios at each test of Subjs. IC and CL, who were tested in the suggestion approximately every day for twelve days. IC, to whom the suggestion was given in the trance, shows a rapid fall in the first three waking tests, followed by a gradual but fairly steady rise. These results, when compared with those secured from the subjects of Group Ia, seem to indicate that frequent tests, involving practice of the suggestion, shorten the period of initial fall and hasten the establishment of the behavior at a large percentage of its original intensity. The record of CL, a normal subject, shows an opposite tendency. The ratio increases greatly during the first week to a ratio far above that suggested, then shows a tendency toward a fairly rapid fall. The onset of this fall, probably indicating a decrease in effort to obey the instructions, occurs sooner than in the case of normal subjects who were given tests less frequently.

In order to determine whether, in the course of each test, the subject showed an improvement in performance, a new treatment of the data was undertaken. The fourteen pages read were divided into three groups; pp. 49–53, 53–59, and 59–63. The average ratio of the breathing rates for each of these groups was computed for each S. Five out of the six trance subjects show a marked tendency to better performance on the second group of pages than on the first, and the average for the trance subjects shows a general improvement from the first group of pages to the second, and a slight improvement from the second to the third. This means that the trance subjects at each time of testing increased their ratio as they read. The data of the normal subjects when treated in this way are less consistent, but when averaged show a tendency in the opposite direction, *i.e.* they start well at each test but fail to keep up the ratio with which they begin. Table III shows the average ratios on each group of pages for the various subjects.

The results of this experiment show a marked difference between the influence of a post-hypnotic suggestion and similar instructions given to control subjects. The main points of difference are as follows:

TABLE III

THE AVERAGE CHANGE IN RATIO ATTAINED BY EACH SUBJECT DURING THE COURSE OF EACH TRIAL, BY COMPARISON OF THE MEAN RATIOS FOR GROUPS OF PAGES

	Mean ratios of subjects of Group I						
Pages	EL	EC	DC	LS	HG	IC	Average
49–52	3.0	3.9	1.6	1.53	3.19	1.93	2.525
53–58	3.3	4.2	1.66	1.65	2.88	2.12	2.635
59–63	3.5	4.4	1.7	1.5	2.87	2.09	2.677

	Mean ratios of subjects of Group II					
Pages	DL	AA	GS	EJ	CL	Average
49–52	12.95	4.37	4.37	14.14	8.28	8.82
53–58	15.46	4.16	3.47	11.94	8.06	8.62
59–63	14.96	4.14	3.43	12.33	8.61	8.69

1. The individual variability in the intensity of the response is far greater in the case of the instructions given in the waking state than to post-hypnotic suggestion. The only conceivable meaning of this, in the opinion of the writer, is a difference in the influence of the first, supervised practice on the succeeding performances. It would appear that the standard set by practice in the trance becomes relatively fixed as a behavior-pattern, while the normal subjects tend to recall at each testing only the words of the instruction and to respond to them as their own faulty sense of rhythm may permit.

2. The records of the trance subjects show a sharp fall during the first few weeks, while the records of the normals show a corresponding rise, in some cases to ratios exceeding the one suggested. Whether this normal rise is due to a practice effect and to a general improvement in controlling the breath or to increased inability to remember the standard set for them is open to question. The writer is inclined to believe in the latter interpretation, since the rise is most marked in the case of those subjects whose first independent performance, being far beyond the appointed rate, reveals an inability to judge at what rate they are breathing. Accordingly, one may say that while the power of post-hypnotic suggestion steadily decreases during the first three weeks after it is given, obedience to waking instructions shows no loss except in accuracy.

3. After the first sharp fall, the trance subjects seem to have reached a level where the effect of practice and the decrease in the potency of the suggestion neutralize each other, and on this low level obedience to the suggestion may continue indefinitely. The height of this level is closely related to the original intensity of the effect of the suggestion for each subject. The normal subjects also show a tendency to continue on a level to which they have risen and which is, accordingly, much higher.

4. If we accept the interpretation of the first rise of the normal curve given immediately above, it becomes evident that there is a characteristic difference between the effects of practice on the potency of waking instructions and post-hypnotic suggestion, in that a long period without practice seems to revive the influence of waking instruction, whereas any effect that it may have on post-hypnotic suggestion is in the opposite direction. In short, practice tends to increase the influence of post-hypnotic suggestion and to decrease that of waking instruction.

5. A fifth difference between the responses to the two forms of instruction lies in the characteristic improvement, during each separate testing, of post-hypnotic suggestion, contrasted with a tendency for the obedience to waking instructions to lessen in the course of each test.

The results obtained in this experiment cast a new light on the mechanisms of post-hypnotic suggestion. The writer believes that, unlike the obedience to waking instructions, the response to post-hypnotic suggestion in this experiment is not primarily a response to a verbal memory revived by reintegration on any 'subconscious' or 'dissociated' level; although this verbal memory-trace exists, and can be made explicit by inducing a later trance.

The course of events may be hypothetically reconstructed as follows. In the first trance, verbal instructions are given to the subject and he is also given practice in carrying them out. The verbal instructions given in the trance have no greater immediate force than instructions given in the waking state; but the trance practice that occurs builds up and

automatizes a habit with unusual facility. On waking the subject, the influence of the verbal suggestion, being dissociated from the waking verbal behavior of the individual, is quickly lost. There remains, however, the habit which has been set up, and which, being purely motor, is not appreciably in conflict with the subject's waking behavior on the symbolic level, but has only to contend with a regular respiration. Each practice in this trance-formed habit, however, assists it to maintain itself against the tendency to breathe normally.

In the case of the normal subjects, we must suppose that practice in a motor function given while waking is less efficient than practice in the trance, for the behavior shows no tendency to automatize, but rather is weakened through practice. On the other hand, the verbal suggestion, not being cut off from the verbal behavior of the normal personality, remains potent on a high level of efficiency.

The failure of post-hypnotic suggestion to effect permanent cures in clinical cases does not conflict with this interpretation. By the method generally used, there is no habit set up in the trance, and, as has been seen in this study, the effect of the verbal suggestion is quickly lost. In the cases where it is possible, then, emphasis should be concentrated on low-level functions which may be automatized, rather than on an attempt to reorganize the subject's symbolic behavior. Hypnosis, therefore, can never be a substitute for psychoanalysis and for other methods of treatment which deal with the entire personality; it may, however, be possible to use it to some advantage in conjunction with other methods.

In order to test the theories outlined above, two further studies seem to be called for. It would be desirable to test the permanence of a post-hypnotic suggestion which is entirely on the symbolic level, and an experiment should be carried out which would determine whether a motor-habit is more readily set up in the trance than in the waking state.

(Manuscript received April 6, 1929)

THE RELATION OF VOLUNTARY MOVEMENT TO TREMORS

BY LEE EDWARD TRAVIS
University of Iowa

The occurrence of tremors in healthy persons was recognized as early as 1880.[1] In 1896 Eshner[2] well established the truth of this observation. It may be observed casually that the fingers when extended present small rhythmical movements or tremors which may be shown to occur at a general rate of 8 to 12 movements per second. This tetanic nature of all voluntary effort[3] presents a number of interesting psychophysiological problems. One is the relation of a sudden movement of a part, *e.g.* a hand or a finger, to the tremors. Does the abrupt movement bear a certain relation to the tremors or is it entirely or somewhat independent of them? Neurologists believe that these tremors are due to cortical activity.[4] As it is generally accepted that voluntary movement also is due to cortical activity a crucial problem seems to lie in the relation of a voluntary movement to the tremors.

Apparatus. The recording apparatus consisted of three phonelescopes,[5] a large film wheel, a film box and a film guide. Each of these four units (the three phonelescopes constituted one unit) was mounted on a ¼-inch iron piece which in turn was bolted to a 13-inch concrete wall by means of half-inch expansion bolts. The concrete wall extended

[1] Debove & Boudet, *Arch. de neur.*, 1880–1, 1, 191.

[2] A. A. Eshner, *J. Exper. Med.*, 1897, 2, 301–312.

[3] W. D. Halliburton, *Handbook of Physiology*, Blakiston, 1923, 104–106; W. H. Howell, *Textbook of Physiology*, Saunders, 1928, 46–48.

[4] J. Athanasiu, *J. d. phys. et d. path. gén.*, 1923, 21.

[5] 'Phonelescope' is the trade name of a standard instrument designed and sold by H. G. Dorsey, 1 Essex Ave., Gloucester, Mass. The instrument is an optical lever. A very small mirror mounted on jewel bearings is activated by a sensitive membrane. A beam of light focused upon the movable mirror is reflected to the photographic film.

several feet into the ground. This type of set-up offered exceptional stability and freedom from jar.

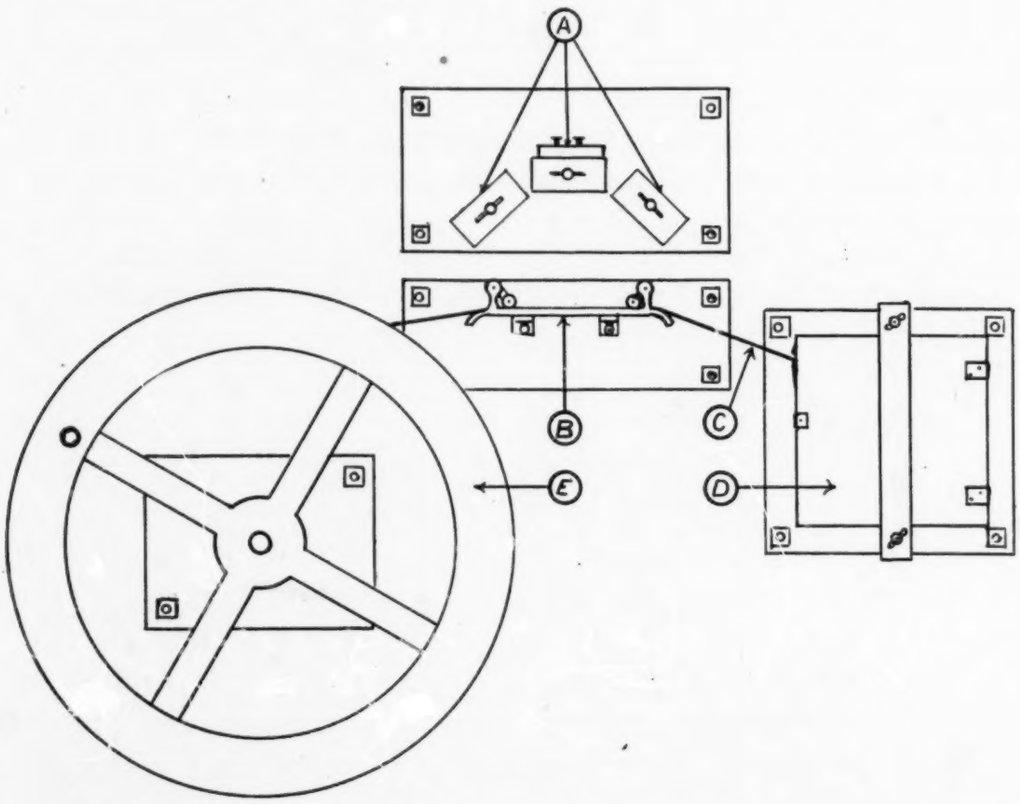

FIG. 1. Diagram of the recording apparatus. *A* = phonelescopes (the middle one was used for recording time); *B* = film guide; *C* = film; *D* = 200-foot film box (Eastman Kodak Company); and *E* = film wheel. The sources of light for the phonelescopes are not shown.

One phonelescope was used to record time. An electromagnetic type of telephone receiver was screwed in its back and connected to a sixty-cycle current which had been passed through a stepdown transformer (110/24) and a 2-microfarad condenser. The other two phonelescopes were used to record the tremors and voluntary movements. To record these, the forefinger was placed directly on the membrane of a phonelescope.

In order to isolate as nearly as possible a single muscle group, the hand was supported on a heavy cross bar which was mounted on a massive tripod. The immobilization of the hand eliminated the effects of movements coming from other parts of the body and offered in a relatively pure form only the movements of the extended forefinger.

The types of voluntary movement studied are as follows: (1) sudden depression of the right forefinger, (2) sudden depression of the left forefinger, (3) sudden elevation of the right forefinger, (4) sudden elevation of the left forefinger, (5) sudden simultaneous depression of the right and the left forefinger, and (6) sudden simultaneous elevation of the right and the left forefinger. All of these movements were made both when the subject moved the finger as he chose and as he moved it only on command from the experimenter.

The recording was done on Eastman standard size, super-speed moving-picture film. Between voluntary movements the subject was required to keep the beam of light approximately equal distances from the two sides of the film.

The Types of Relationship

From fifty to six hundred voluntary movements were recorded from each of fifteen normal male subjects. Five types of relationship between the voluntary movements and the tremors obtain for both elevation and depression of either forefinger or of both forefingers under both conditions of experimentation, *i.e.* spontaneous movement and movement upon command. These types are shown in Fig. 2 and Fig. 3.

For depression (Fig. 2) Type I shows the voluntary movement to be a continuation of the descending phase of a tremor. In Type II the voluntary movement begins in the middle of the ascending phase of a tremor thus giving an apparent interruption of the tremors. Types III, IV, and V are probably variations of Type I. In these three instances the voluntary movement begins at a time which indicates that it may be a continuation of the downward phase of a tremor. In this sense there is no interruption of the tremors. In Type III the last tremor before the depression consists of two smaller movements, while in Type IV it does not appear at all. Type V shows the last two tremors before the depression to be fused into one, which presents an unusual height just before the depression.

For elevation (Fig. 3) Type I shows the voluntary move-

ment to be a continuation of the ascending phase of a tremor. Type I of elevation is homologous to Type I of depression. Type II presents a delay in the ascending phase of the tremor on which the elevation appear. The tremors are, therefore, apparently interrupted. Types III, IV and V of elevation

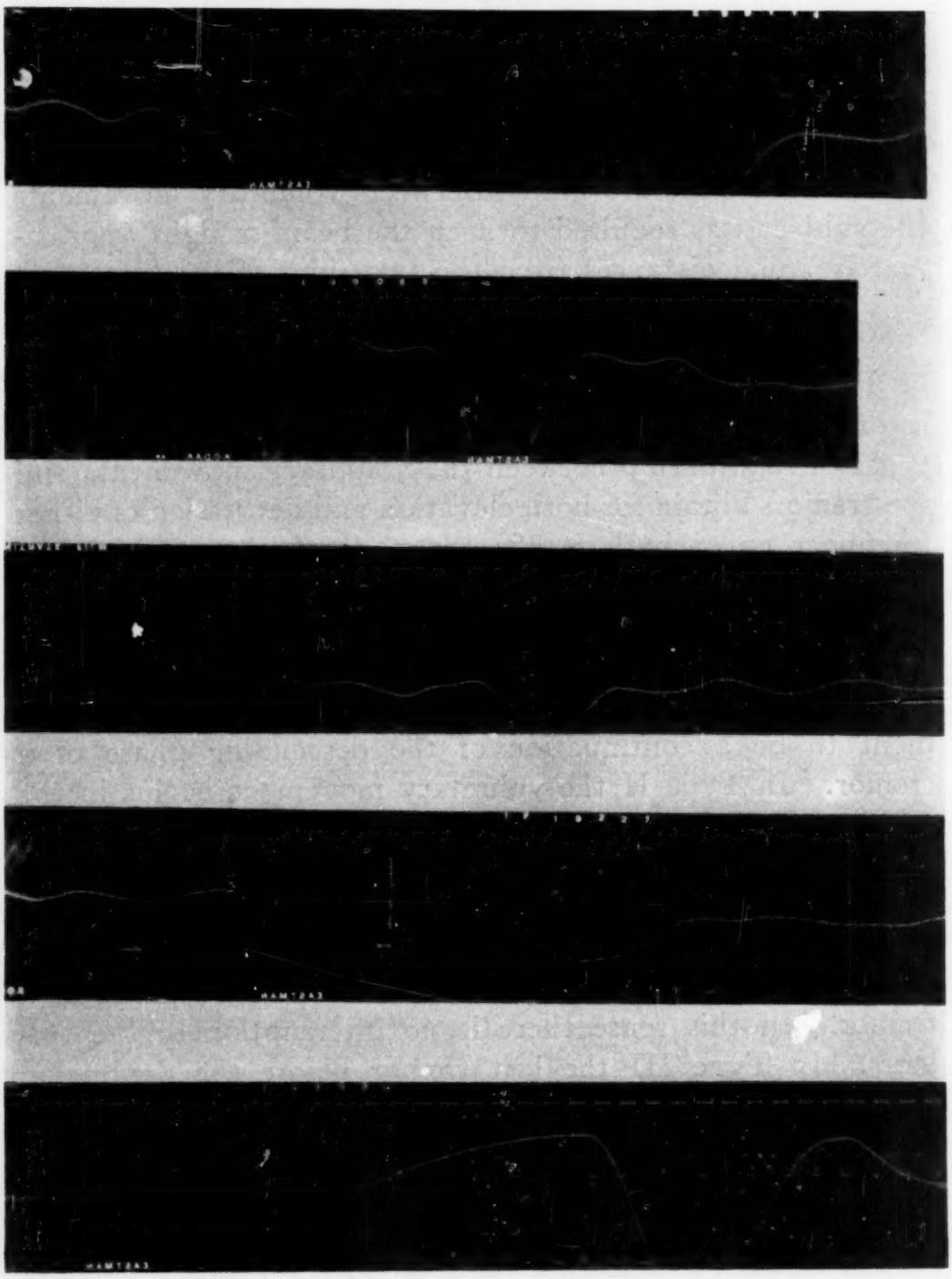

FIG. 2. Records of depression of the forefinger

are homologous to Types III, IV and V of depression and are undoubtedly modifications of Type I. In each instance the elevation comes at the proper time to be a continuation of the upward phase of the tremor were the tremor to appear. In Type III the last tremor consists of two smaller tremors,

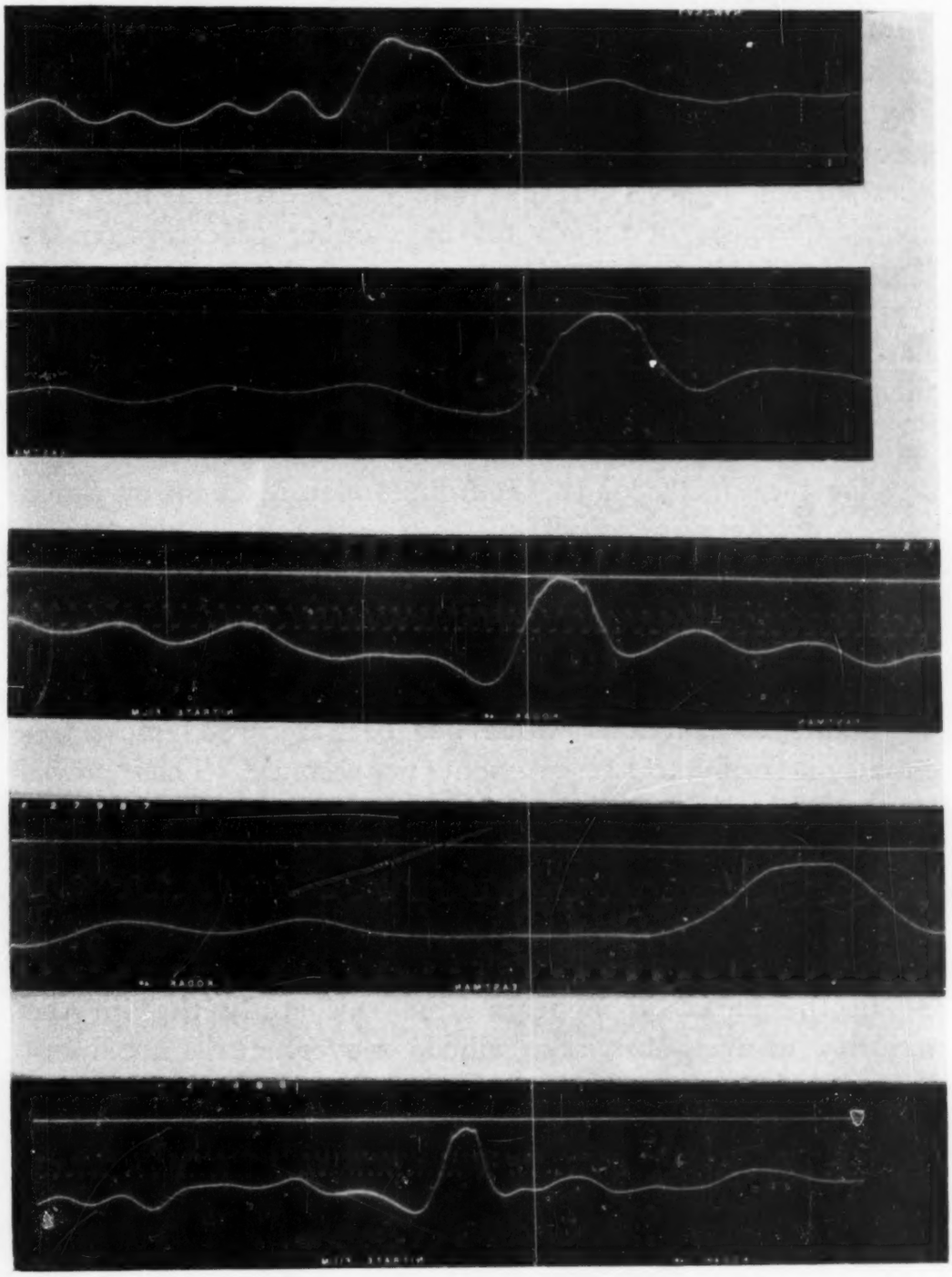

FIG. 3. Records of elevation of the forefinger

while in Type IV it does not appear at all. In Type V there is a blending of the last two tremors before elevation.

For depression and elevation of either forefinger or of both forefingers at the same time under both conditions of experimentation, about seventy-five percent of the relationships between voluntary movement and the tremors belong to Type I. A voluntary movement is, in most instances, a continuation of a tremor and does not interrupt the tremor rhythm. There appears to be no marked difference in the frequency of occurrence of the other four relationships as presented in Types II, III, IV and V. Individuals may present differences in regard to the number of exceptions to Type I. It is noteworthy that one individual presented Type I 100 percent of the time. This phase of the study has not been sufficiently investigated to make a definite statement concerning it.

Discussion

The motor side of the neuromuscular mechanism which comes into play in voluntary movement consists of at least two neurons and the muscle. It has been supposed by physiologists that if in voluntary effort the muscular contractions are tetanic, the motor nerve cells transmit a series of nerve impulses through the motor nerve into the muscle. The rate of tetanic contractions which has been recorded most frequently is from 8 to 12 movements per second.[6] These movements appear in any part of the body which is being maintained by voluntary effort in any given position. If by a so-called act of the will we suddenly alter the position of a part of the body, what is the relation of the 'willed' movement to the rhythmical movements which have been appearing in the part? It appears from this study that in the majority of instances the 'willed' movement is not independent of the tetanic contractions, in the sense of interrupting them, but blends into the rhythm already established. The voluntary intention fits into the kinetic melody. Types

[6] These contractions in turn are undoubtedly fusions of contractions occurring at a more rapid rate. A. V. Hill, *J. Physiol.*, (*Physiol. Soc.*, lv), 1921; L. E. Travis & T. A. Hunter, *Amer. J. Physiol.*, 1927, 81, 355–359.

III, IV and V, however, present evidences of anticipatory hesitation which interferes in some way with the tetanizing series of impulses. Type II, of course, indicates a definite interruption of these tetanizing series of impulses.

At this point in our thinking it occurred to us that the interpretation of our result would be more valuable if first-hand knowledge of the source of the tremors could be gained. Consequently, the study was extended to include neurological cases.

Case I: *Neurosyphilis, meningo-vascular type.* Partial right-sided hemiplegia; a negro male, age 44. Two years before the tremor records were obtained the patient had a paralytic stroke which resulted in complete loss of voice and a complete paralysis of the right side. Within three days he had recovered the use of his voice but for three weeks he was unable to walk. The right arm has never completely recovered. There was no loss of sensation. During the past two years the patient has had several attacks which would begin with a 'muscular drawing' in the neck and right arm and the right lower lid would pull down. Then he would become unconscious and remain so for about 30 minutes.

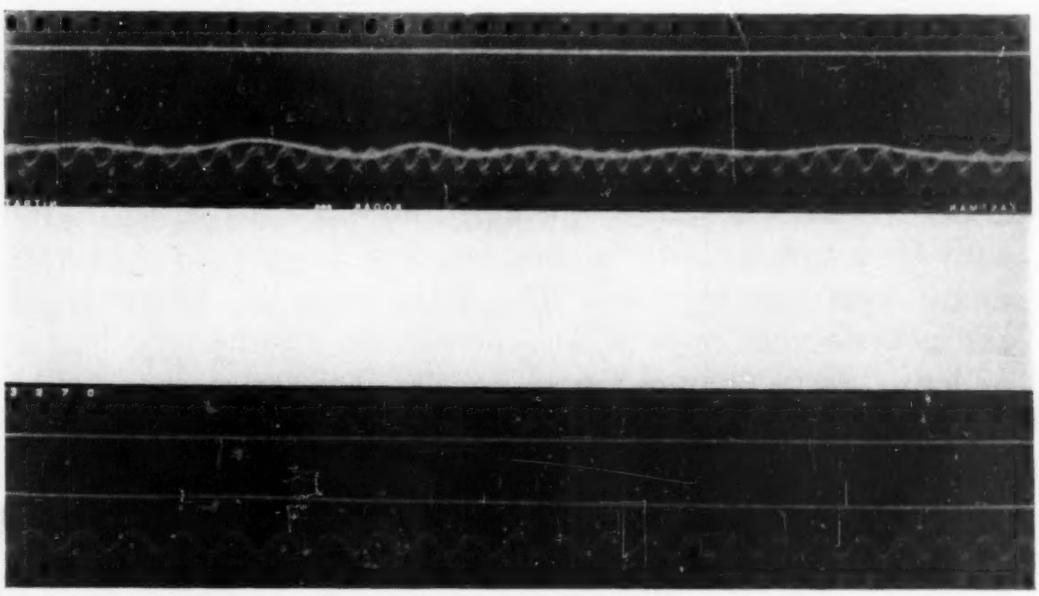

FIG. 4. Records of tremors from Case I. The top record shows the tremors from the left forefinger and the bottom record from the right forefinger.

At the time the tremor records were obtained the patient presented a marked reduction in the strength of the grip of the right hand and practically a complete loss of the movement of the fingers of the right hand. All deep reflexes were exaggerated on the right side. The Wassermann reaction was 2 plus in the spinal fluid and plus-minus to both antigens in the blood. Records from the right forefinger showed slight evidence of tremors. Records from the left forefinger showed tremors of the normal rate and extent. Sample records from the two fingers are shown in Fig. 4.

Case II: *Arteriosclerosis, cerebral.* Cerebral hemorrhage, complete right hemiplegia, deep right hemianæsthesia; a white American male, age 64 years. About a year before the tremors were recorded the patient fell but did not lose consciousness. He was unable to get up because of weakness of the right side. He remained in bed only one day. About eleven months later the patient fell and was unconscious for some time. The entire right side was completely paralyzed and numb.

At the time the tremor records were obtained the patient presented a complete right hemiplegia, deep right hemianæsthesia, Babinski on the right, and exaggerated deep reflexes on the right side. All laboratory findings were negative.

Records from the right forefinger showed no tremors. Records from the left forefinger showed tremors of the usual rate and extent.

Case III: *Chronic endocarditis.* Mitral stenosis, cerebral embolus, complete left hemiplegia, partial deep left hemianæsthesia; a white American female, age 36 years.

About three weeks before the tremors were recorded the patient had a stroke which left her left side completely paralyzed. At the time of recording the tremors the patient presented a complete left hemiplegia, partial left hemianæsthesia, and exaggerated deep reflexes on the left side. All laboratory findings were negative. Records from the left forefinger showed no tremors. Records from the right forefinger showed tremors of the usual rate and extent.

If the rapid tetanus is due to tone-reflex arcs (lower centers), then the cortical impulses can act only when the lower cells are in the phase of conducting impulses and can not act when the lower centers are in a resting (recovering) phase. If the tetanus is due to cortical aetivity, then the cortical arcs function in a rhythmical way and the outcome of the study of normals would indicate that when the cortical arcs shift from one activity to another they do so mainly in harmony with this rhythm. The main point in the study of the neurological cases was to determine whether the higher or lower nerve centers are responsible for the tremor. The type of patients studied indicates that the higher nerve centers are the source of the tremor because when the cortical paths were interrupted with the lower levels left intact (evidenced by loss of voluntary motion with the presence of exaggerated deep reflexes on the affected side) the tremors were not present. There is some question about the localization of the lesions in these patients; but there can be no doubt about the more or less complete interruption of function of the pyramidal tracts with the function of the lower reflex arcs remaining intact. To say positively that the tremor is due to cortical activity is probably unwarranted inasmuch as the mid-brain centers have not been ruled out.

But the study of these patients lends support to the view of neurologists that the tremors are of cortical origin.

The significance of this study in relation to such problems as reaction time may be seen by studying Fig. 5. The sub-

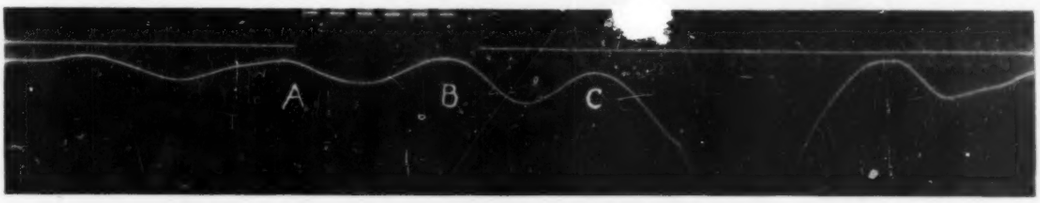

FIG. 5. Record of depression of the forefinger. The first break in the signal line indicates the instant of giving the auditory stimulus to depress the finger.

ject in this record could have reacted at the beginning of the downward phase of any rhythmical movement subsequent to the stimulus. His reaction time might have been the interval of time between A and B, .116 sec instead of between A and C, .232 sec. Why it was the latter rather than the former is unknown; but that in the majority of instances he would have had a reaction time of .116 sec or a multiple thereof seems quite well established and of marked importance. Reaction time depends upon the temporal relation of the stimulus to the muscular rhythms. Variations in this relationship from one reaction time to another may account partially at least for the variations in reaction time for the same individual.

Another problem touched upon by this study is the maximal rate of repeated voluntary movements of any given part of the body. According to the interpretation of our results one cannot move a part at a higher frequency than that of the muscular rhythms—8 to 12 movements per second. In the tapping test of experimental psychology it is significant that, to our knowledge, no worker has ever reported a rate of tapping greater than 12 taps per second. The maximal rate is limited by the refractory phase of the arcs involved. At what rate the individual actually taps may be dependent upon other factors, but his maximal rate is determined by the rate of discharge of the cortical arcs which he cannot voluntarily alter.

SUMMARY

1. In sudden depression and elevation of either forefinger or of both forefingers at the same time, it was found that in the great majority of instances a sudden voluntary movement blends into the tremor rhythm so as to be a continuation of the downward or of the upward phase of a tremor.

2. In certain instances it appeared that a sudden voluntary movement may interrupt the tremor rhythm or interfere in some way with the tetanizing series of impulses.

3. A study of three hemiplegics showed that the tremors are entirely absent on the completely paralyzed side.

4. It appears that reaction time depends upon the temporal relation of the stimulus to the tremors and that the maximal rate of repeated voluntary movements of any given part of the body is limited by the tremor rate (8 to 12 movements per second).

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